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SIMON NEWCOMB

By ORMOND STONE

Simon Newcomb was a unique figure in American science.[1] Perhaps no other great American scientist was so many sided, no other, who approached him in versatility, stood at or so near the head in various departments of science. He was mathematician; celestial mechanician; astronomical observer, computer, and statistician; fundamental star cataloguer; author of memoirs on the lunar theory, of planetary tables, of books on popular astronomy, of mathematical school and college texts, of books on economics; novelist; president of a society for psychical research!

Simon Newcomb was born March 12, 1835, in Wallace, a village of Nova Scotia, but he was of New England descent. At the age of seventeen he went to Salem, Mass., and later to Maryland, where he taught school for several years. When twenty-two he became assistant in the *Nautical Almanac* office, then located at Cambridge, Mass., and also a student in the Lawrence Scientific School, where he later graduated as Bachelor of Science. At the age of twenty-five he received an appointment as professor of mathematics, U. S. N., and was assigned to duty in the Naval Observatory in Washington. Sixteen years later he was placed in charge of the *Nautical Almanac* office, which had been removed to Washington and of which he

[1] The portrait of Professor Newcomb, reproduced herewith, is from a photograph made in 1897 by Mr. A. D. Wyatt, of Brattleboro, Vermont. It therefore represents Professor Newcomb at the age of sixty-two, in the year of his retirement from active service in the Navy Department.—EDS.

remained director from 1877 until 1897, when, having reached the age of sixty-two, he was placed on the retired list. He continued to reside in Washington until he died, July 12, 1909. Upon the death of Professor Winlock, in 1875, he was offered but declined the directorship of the Harvard Observatory. From 1884 to 1894 to his duties in the *Nautical Almanac* office he added those of professor of mathematics and astronomy at the Johns Hopkins University and editor of the *American Journal of Mathematics*. In what follows no attempt will be made to give more than the briefest outline of the more important of his astronomical activities.

The first work that called attention to his genius for research was carried out in Cambridge while he was an assistant in the *Nautical Almanac* office there. The final results were communicated in 1860 to the American Academy of Arts and Sciences in a paper showing, among other things, that so far as present theory could determine, the orbits of the asteroids had never passed through any common point of intersection. There was thus no evidence that these little planets were fragments of a larger planet which had suffered a cataclysm at some epoch in the distant past, as suggested by Olbers.

In 1862 the 8-inch transit circle of the Naval Observatory was received and placed in charge of Professor Newcomb, who proceeded to observe the stars of the *American Ephemeris* and other miscellaneous stars. During 1866 and 1867 the observing programme was so arranged that as far as possible groups of stars were observed about twelve hours apart in order to determine the systematic errors of the star places given in the *Ephemeris*, and thus obtain results independent of previous observers. In the volume of Washington observations for 1870 Professor Newcomb published a memoir on the right ascensions of the equatorial fundamental stars and the corrections necessary to reduce the right ascensions of different star catalogues to a mean homogeneous system. In the first volume of the *Astronomical Papers of the American Ephemeris*, a magnificent series of volumes founded by Professor Newcomb and continued by him during his directorship of the *Nautical Almanac* office, he published another fundamental catalogue, this time giving both right ascensions and declinations, derived from all the data then available, as had been the catalogue previously mentioned. And finally, in the eighth volume,

is given a new determination of the precessional constant and a catalogue of fundamental stars for the epochs 1875 and 1900, reduced to an absolute system. This catalogue contains no less than 1596 stars and is a masterpiece of exhaustive research. The positions given are likely to remain the standard for some time to come, probably at least until the observations of Piazzi, Maskelyne, Bessel, and Pond have been re-reduced. They have already been introduced into the principal national ephemerides of the world.

Professor Newcomb at an early date became interested in the question of the sun's parallax, and in 1869 published an investigation based upon all the data then available. The result at once became the standard and so remained for many years. Later, as a member of the Transit of *Venus* Commission, he took an active part in preparing for and directing the expeditions sent by the United States to various parts of the world to observe the transits of *Venus* that occurred in 1874 and 1882. Still later he made a careful study of the transits of 1761 and 1769, obtaining results agreeing well with those obtained from more modern observations. In connection with this investigation, after examining the original records, he vindicated the honesty of the much-maligned Father Hell, who was one of the principal observers of the transit of 1761 and was afterward accused of "cooking" his observations. The importance of the velocity of light as a means of determining the sun's distance caused him to become interested in Michelson's experiments, and led him to make similar experiments himself. The accuracy secured far exceeded that of values previously obtained. Professor Newcomb's discussion of all the determinations of solar parallax given in the supplement to the *American Ephemeris* for 1897 may be considered the last word on the subject up to the present time.

In 1865 Professor Newcomb published an investigation of the orbit of *Neptune*, including tables of its motions. A similar treatise on the motions of *Uranus* was published in 1873. Both of these memoirs appeared in the *Smithsonian Contributions to Knowledge*. Having thus begun the study of the motions of the solar system, on taking charge of the *Nautical Almanac* office, he "deemed it advisable to devote all the force which he could spare to the work of deriving improved values of the fundamental elements and embodying them

in new tables of celestial motions." This gigantic purpose he lived to see completed so far as the major planets were concerned. As the orbits of *Neptune* and *Uranus* were the first to receive his consideration, so the tables of these planets based upon newly revised theories were his last contribution to the *Astronomical Papers* before his retirement from the *Nautical Almanac* office.

For the solution of the problem of their motions the major planets were separated into three divisions: (1) The four inner planets; (2) *Jupiter* and *Saturn;* (3) *Uranus* and *Neptune.* Reserving for his own consideration the four inner and the two outer planets, he assigned the orbits of *Jupiter* and *Saturn* to Dr. G. W. Hill, stipulating merely that care be taken to make the work of the latter homogeneous with the work on the other major planets; for instance, the values of the masses of *Jupiter* and *Saturn* to be used were to be assigned by Professor Newcomb. In order to obtain an accurate determination of the mass of *Jupiter*, a careful study was made of the motions of the asteroid *Polyhymnia*, the eccentricity and major axis of whose orbit are so large that at times it approaches so near to *Jupiter* as to give rise to large perturbations.

As a supplement to the *American Ephemeris* for 1897, Professor Newcomb published a brief summary entitled "The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy." All known meridian observations of the sun and of the planets *Mercury*, *Venus*, and *Mars* were reduced to a uniform equinox and system of declinations and compared with Leverrier's tables. A similar exhaustive comparison was made for the transits of *Venus* and *Mercury*. The results of these comparisons were then combined and upon them was based a new determination of the orbits of the four inner planets, including a more accurate determination of the deviation of the observed values of the motions of the perihelion of *Mercury* and of the node of *Venus* from the values computed in accordance with the law of gravitation. It was found that the observed discrepancies could be accounted for by assuming a ring of matter lying between the orbits of *Mercury* and *Venus*. Professor Newcomb's conclusion was, however, for reasons which he gave, that we cannot, in the present condition of knowledge, regard this hypothesis as more than a curiosity.

It is true the discussion of theoretic methods of celestial mechanics was carefully subordinated by Professor Newcomb to the practical purposes kept steadily in view. Only in this way was it possible to accomplish such monumental practical results. Nevertheless, his work did not consist merely in applying the methods of others to the determination of the actual motions of the planets under consideration; his own contributions to planetary theory were important. In 1874 his paper "On the General Integrals of Planetary Motion" appeared in the *Smithsonian Contributions to Knowledge*. Assuming that the differential equations of motion can be satisfied approximately by infinite series containing only terms of the forms

$$p=c\cos(a+bt) \text{ and } q=a+bt$$

where t is the time, and a, b, c are arbitrary constants, he showed that these series could be replaced by similar ones having a higher degree of approximation, and thus the problem of three bodies could be solved formally by series containing no terms except of the given form. Poincaré devotes a large part of the second volume of *Les méthodes nouvelles de la mécanique céleste* to applications of Lindstedt's method, which he shows is essentially that of Newcomb just mentioned.

Professor Newcomb's researches on the motions of the moon began with a paper read before the American Association for the Advancement of Science at its meeting in 1868 and written to show that there is no good reason to suppose that there is any want of coincidence between the center of figure and the center of gravity of the moon as maintained by Hansen. Next followed various papers calling attention to the extraordinary differences existing between the positions of the moon as given in Hansen's tables and as obtained from the latest observations made at Greenwich and Washington. The elements used in Hansen's tables were based on observations made between 1750 and 1850. Having found that these tables failed to satisfy later observations, Newcomb compared them with all known observations made before 1750. This investigation was aided by a visit to the principal observatories of Europe which led to the discovery, especially in Paris, of numerous and valuable unpublished observations of eclipses and occultations. Also, a large part of the published observations had not before been used for determining the

moon's place. The comparison when completed disclosed discrepancies that could be explained in two ways: (1) By supposing the discrepancies to be only apparent, arising from inequalities in the axial rotation of the earth; (2) By assuming empirically a correction to Hansen's value of a term depending on the action of *Venus* and having a period of 273 years. Later, from the exhaustive study of the transits of *Mercury* from 1677 to 1881, already referred to, it was inferred that the discrepancies between the observed and the computed positions of the moon could not be accounted for on the assumption of inequalities in the axial rotation of the earth, and that "inequalities in the motion of the moon not accounted for by the theory of gravitation really exist." The last work performed by Professor Newcomb, while his life was nearing its end, was a comparison with Hansen's tables of all the observations of the moon to date, made with the aid of a grant from the Carnegie Institution, a result of which was the confirmation of the existence of deviations apparently not accounted for by the law of gravitation. The larger part of these he found could be reduced to a single term, as previously suggested, but the existence of well-marked smaller outstanding deviations of an apparently irregular character was also clearly shown.

While the comparisons of Hansen's tables with observations is probably the permanent result of greatest value that Professor Newcomb contributed to the study of the moon's motion, laying as it does a firm foundation upon which to base the determination of the numerical values of the constants employed, whatever method may ultimately be adopted for the analytical discussion, nevertheless, as in the case of his study of planetary theory, his theoretical study of the lunar problem would by itself have been sufficient to have secured for him a high and enduring place in the history of the subject. His most important contribution to lunar theory related to the action of the planets on the moon. His first memoir on this subject appeared in *Liouville's Journal* in 1871. Afterward he published a rediscussion of the problem in the *Astronomical Papers*. Only a few years before his death he took up the whole subject again and published a final memoir in 1907 under the auspices of the Carnegie Institution.

Among Professor Newcomb's other investigations may be mentioned determinations of the orbits of the satellites of *Uranus* and

Neptune from observations made with the 26-inch refractor of the Naval Observatory, and his paper on *Hyperion*, explaining the remarkable retrograde motion of the line of apsides of that satellite.

His *Spherical Astronomy* and *The Stars* are both in their way pioneers and will ultimately be ranked among the classics of astronomical literature. *The Stars*, while essentially a statistical research on the structure of the universe, is written in a simple and lucid style that gives it an interest to others beside astronomers. As a result of his remarkable power of discussing scientific subjects in a manner capable of comprehension by the intelligent general reader, his popular works on astronomy are models of their kind and have the advantage that, being written by a master of his subject, they have an intrinsic and enduring value not possessed by most other works of that class. His ability as a popular writer is also seen in his *Reminiscences*, which is one of the most attractive autobiographies ever written.

Recognition of the fact that Professor Newcomb was the leading astronomer of his time was shown by his election to honorary or corresponding membership in all the great scientific societies of the world and by the numerous medals, academic titles, and other distinguished honors that were showered upon him.

Leander McCormick Observatory
University of Virginia
September 1909

UPON THE SEPARATION OF THE SPECTRAL LINES OF THORIUM IN THE MAGNETIC FIELD. II[1]

By B. E. MOORE

Tables XII–XVI inclusive contain a list of unsymmetrical lines exclusive of triplets.

Table XII is an unsymmetrical 9-component line. There are two red and one blue *p*- components. The latter is double the inside red component. The remaining red component has the value of the "normal" triplet, but it is not related in a simple way to the other *p*- separations, nor to the separations of the *s*- components.

TABLE XII

λ 3722.06	
i	$\Delta\lambda/\lambda^2$
2	+1.59 *s*
2	+ .99 *s*
8	+ .90 *p*
2	+ .38 *s*
2	− .32 *s*
2	− .45 *p*
2	−1.02 *s*
6	−1.11 *p*
1+	−1.62 *s*

TABLE XIII

λ 3959.38	
i	$\Delta\lambda/\lambda^2$
1	−2.00 *s*
1	−1.42 *p*
1	− .80 *s*
5	0. *p*
1	+ .98 *s*
1+	+1.23 *p*
1+	+1.87 *s*

Table XIII is an unsymmetrical 7-component line. Both *p*- and *s*- are unsymmetrical; but the strong undisplaced *p*- component is the only one which can be measured with desirable accuracy.

Table XIV gives four 6-component lines. The footnotes indicate their principal features.

Table XV contains seven 5-component lines. At least six of these are unsymmetrical with respect to the *p*- component only. Line λ 4115.85 has its components in the ratio of (0, 1, 3, 4) times 0.417. The first three values represent the unsymmetrical *p*- components and the latter the symmetrical pair of *s*- components. In the *p*-components of λ 3938.86 one finds (0, 2, 3) times 0.41, which is practically the same interval as in the previous line. The *s*- com-

[1] Continued from p. 166.

ponents of this line are not related to this interval. However, we may combine both *p*- and *s*- components together as multiples of the interval $a/11$. We then have (0, 8, 12, 14) times $a/11$. Applying this interval to the previous line gives larger discrepancies in the readings. In line λ 3709.82 the *s*- components are nearly in the ratio of one to two in separation and in the ratio of three to one in intensity.

Table XVI contains thirty-three quadruplets. Twenty-four of these have unsymmetrical *p*-, and fifteen unsymmetrical *s*- components. There are six of these lines "lop sided," i. e., there are more components on one side of the middle than on the other. For three of these lines, λ 4619.67, 4318.65, and 4105.55, the mean of the two separations upon one side is symmetrical with the position of the third component upon the other side of the middle. This is probably also true for λ 4050.02, but does not hold for λ 4036.22. The distance between these two components is very different for these lines. For line λ 4619.67 the two *s*- components on the one side do not appear separated on the weaker field plate, but present the appearance of a broadened line. There are one to two, one to three, two to three, and three to four ratios represented in the separations of components, which are usually expected to have equal values. Some of these ratios are represented more than once, but then the lines are unlike because the ratio factors must be multiplied by different magnitudes to produce the observed separations. Two lines which have the same magnitude of separation in *p*- or *s*- usually have quite different magnitudes in their respective *s*- or *p*- components, as was noted in the symmetrical quadruplets. This greatly reduces the possibility of duplicates.

Table XVII contains a list of symmetrical triplets. In the column of intensities, the red component appears first, the unseparated *p*-component next, and the blue *s*- component last. These lines are further illustrations of the fact that there are no appreciable steps in the value of triplets. When they approach each other so closely in magnitude, it is scarcely possible to isolate lines of a certain magnitude of separation and intensity and group them into series or related lines. Under such circumstances, it would be much less meaningless to say that lines of similar types repeat themselves from substance

TABLE XIV

λ 4295.25*		λ 3998.01†		λ 3828.58‡	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1.....	−2.45 *p*	—.....	... *s*	2.....	− 1.63 *s*
1.....	−1.94 *s*	—.....	... *s*	1.....	− .90 *s*
5.....	−1.11 *s*	12.....	−.66 *p*	7.....	− .55 *p*
12.....	0. *p*	10.....	+.97 *p*	5.....	+ .45 *p*
7.....	+1.11 *s*	—.....	.. *s*	2.....	+ .96 *s*
1.....	+1.77 *p*	—.....	.. *s*	1.....	+(1.30) *p*

*The outside pair of *p*- may be foreign. In second order the zero *p*- is diffuse on the red, looking like a companion weak line. No-field plate line is also diffuse on the red. The middle of the *s*- was assumed to be midway between the two stronger components. If there are two lines here the principal one is a symmetrical triplet and the weaker one a symmetrical quadruplet with the separation of *p*- greater than *s*-.

†There are four if not six components in each of the *s*-.

‡The outer blue component possibly belongs to the adjacent line.

λ 3678.19*	
i	$\Delta\lambda/\lambda^2$
1+....	−2.20 *s*
2......	−1.36 *s*
10......	− .26 *p*
4......	+ .26 *p*
4......	+ .88 *s*
2......	+2.08 *s*

*On no-field plate second order there are two lines, unless it is reversal which should have shown in first order. Exner and Hascek give but one line. Supposing it two lines, the inner pair of *s*- are symmetrical with the stronger line (or red *p*-), but one is at loss to know how to dispose of the outer pair of *s*-.

TABLE XV

λ 4342.45		λ 4115.85		λ 4100.57	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1—...	−(1.56)? *s*	2......	−1.66 *s*	2.....	−1.64 *s*
6.....	1— 1.11 *s*	2......	− .84 *p*	2.....	− .52 *p*
12.....	− .54 *p*	2......	0.00 *p*	1+...	0 00 *p*
5.....	+ .80 *p*	1+....	+ .42 *p*	3.....	+ .69 *p*
6.....	+ 1.10 *s*	2......	+1.66 *s*	3.....	+1.64 *s*

TABLE XV—CONTINUED

λ 4075.92		λ 3938.86		λ 3822.33	
i	$\Delta\lambda/\lambda^2$	*i*	$\Delta\lambda/\lambda^2$	*i*	$\Delta\lambda/\lambda^2$
2	— .80 *s*	3	—1.39 *s*	6	—1.03 *s*
3	—1.27 *p*	3	—1.23 *p*	4	— .85 *p*
3	0.00 *p*	1	0.00 *p*	2	— .17 *p*
3	+ .95 *p*	8	+ .81 *p*	2	+1.12 *p*
1+	+ .80 *s*	4	+1.39 *s*	3	+1.33 *s*

λ 3709.82	
i	$\Delta\lambda/\lambda^2$
1	—(1.55) *p*
1	—(.97) *s*
5	0.00 *p*
3	+ .50 *s*
—	+ ? *p*

TABLE XVI

λ 4619.67		λ 4352.87		λ 4347.40	
i	$\Delta\lambda/\lambda^2$	*i*	$\Delta\lambda/\lambda^2$	*i*	$\Delta\lambda/\lambda^2$
1+	—1.17 *s*	3	—1.35 *s*	2	—1.62 *s*
2	—1.04 *s*	12	— .51 *p*	4	— .43 *p*
10	0.00 *p*	4	+1.03 *p*	1+	+ .81 *p*
5	+1.11 *s*	3	+1.35 *s*	2	+1.62 *s*

λ 4318.65		λ 4165.92		λ 4164.43	
i	$\Delta\lambda/\lambda^2$	*i*	$\Delta\lambda/\lambda^2$	*i*	$\Delta\lambda/\lambda^2$
5	—1.45 *s*	1	—(1.05) *s*	5	—1.18 *s*
10	0.00 *p*	3	— .99 *p*	4	— .71 *p*
3	+ .89 *s*	4	+ .76 *p*	3	+ .44 *p*
1	+2.00 *s*	1	+(.88) *s*	3	+1.18 *s*

TABLE XVI—CONTINUED

λ 4105.55		λ 4060.05		λ 4050.02	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
2......	—1.31 *s*	1......	—(1.03) *s*	3.....	—1.59 *s*
1......	— .76 *s*	1—....	—(.70) *p*	8.....	0.00 *p*
8......	0.00 *p*	2	+(.36) *p*	1....	+ .84 *s*
6	+1.04 *s*	1......	+(1.03) *s*	1.....	+2.44 *s*

λ 4036.22		λ 4027.15		λ 3993.86	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1.....	—1.73 *s*	2.....	—1.15 *s*	1.....	—(1.10) *s*
1.....	— .55 *s*	3.....	— .27 *p*	1+..	—(.38) *p*
6......	0.00 *p*	2	+ .38 *p*	1.....	—(.76) *p*
3.....	+1.84 *s*	2.....	+1.15 *s*	1.....	+(1.10) *s*

λ 3955.28		λ 3895.55*		λ 3873.56	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1+....	—1.53 *s*	8......	—1.02 *s*	2.....	— .66 *s*
5......	— .74 *p*	5......	— .11 *p*	5.....	— .31 *p*
3......	+1.38 *s*	2......	+ .23 *p*	1.....	+ .96 *p*
2......	+1.48 *p*	8.....	+1.02 *s*	1.....	+1.30 *s*

*The *s*- measured in first, the *p*- in second order.

λ 3867.42		λ 3866.21		λ 3842.69	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1......	— .38 *s*	7......	— .60 *s*	2.....	—1.25 *s*
3......	— .42 *p*	3......	— .82 *p*	2.....	— .38 *p*
1+....	+1.32 *p*	6	+ .46 *p*	1... .	+ .76 *p*
1......	+ .38 *s*	3.....	+1.26 *s*	1.....	+1.56 *s*

TABLE XVI—CONTINUED

λ 3838.01		λ 3827.07		λ 3815.95*	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
2.....	—1.54 *s*	1......	— .66 *s*	3.....	— .53 *s*
4.....	0.00 *s*	3	— .80 *p*	5.....	— .19 *p*
12.....	0.00 *p*	5	+ .52 *p*	1.....	+1.68 *p*
3.....	+1.70 *s*	2......	+ .38 *s*	1.....	+1.73 *s*

*The components of intensity 1 might belong to line 3815.78, the blue components of which are visible. The latter would then be unsymmetrical. If this were accepted then one has no blue components for this stronger line.

λ 3814.12		λ 3813.79*		λ 3790.10†	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1—....	—(.90) *s*	—.....	— .— *s*	5.....	— .51 *s*
1......	—(.79) *p*	3......	— .40 *p*	—....	—0.00 *p*
1......	+(.79) *p*	1......	+ .53 *p*	2.....	+ .68 *s*
2	+(.32) *s*	3......	+1.31 *s*	1.....	+ .98 *s*

*Exner gives 3813.85 for this line which would make the dissymmetry greater.

†The *sr* is overlapped by *sb* of 3790.26.

λ 3783.15*		λ 3778.00†		λ 3776.10	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
—.....	—(1.13) *s*	3......	— .27 *s*	4.....	—1.08 *s*
8......	— .51 *p*	2......	— .27 *p*	6.....	—1.08 *p*
6......	+ 1.00 *p*	1—....	+ .94 *p*	5.....	+1.59 *p*
6......	+(1.13) *s*	1.....	+1.16 *s*	3.....	+1.55 *s*

*The *sr* is overlapped. Exner's 3783.27 not found. Could this be it?

†It seemed that the weak blue components might belong to some other line, which would leave *s*- and *p*- identical in position but only with red components.

TABLE XVI—CONTINUED

λ 3775.47		λ 3771.80*		λ 3770.25	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1—....	—1.05 *s*	3......	— 1.05 *s*	—....	—(1.17) *s*
2......	— .57 *p*	2......	— .91 *p*	6.....	— .65 *p*
1......	+ .85 *p*	1—....	+(1.81) *p*	4.....	+ .95 *p*
2......	+ .48 *s*	1—....	+(1.55) *s*	3.....	+ .55 *s*

* An overlap on *pb*. The *sb* is broad, possibly double. Its middle measures as given. It is certainly unsymmetrical.

λ 3751.90*		λ 3712.80		λ 3617.88†	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
1—....	—(...) *s*	2......	—1.36 *s*	1—...	— ... *s*
1......	0.00 *s*	3......	—1.30 *p*	2.....	—1.02 *p*
2......	0.00 *p*	5......	+ .59 *p*	1.....	+2.04 *p*
1......	+ 1.46 *s*	2......	+1.36 *s*	1—...	+ ... *s*

* This line may be symmetrical. The *sr* is diffuse.
† The *s-* is diffuse but smaller than *p-*.

to substance, and therefore infer a similarity of the substances. The same is true to a less degree with the quadruplets. A few like separations of any type (Purvis, *loc. cit.*) are useless for comparing similar chemical substances or for inferring a similarity of chemical behavior. However, these like separations have an important bearing upon that very subject, because they are natural starting-points from which to begin the search for a connected relationship in the separations. Only when such relationships repeat themselves from substance to substance can one confidently assert that a similarity in the substances exists.

In such a diversity of separations, it might seem that small errors in the measurements for these triplets would, if corrected, throw them into groups differing by a small but appreciable amount, so that the actual number of separations would be small and possibly related to one another in some simple way, or even related to a normal value. There are, e. g., some well-defined lines

TABLE XVII

λ	i	Δλ/λ²	REMARKS	λ	i	Δλ/λ²	REMARKS
4761.3	1+ , 3 , 1+	.99		4525.04	1 , 4 , 1	(1.17)	*sr o* broad
52.6	3 , 6 , 6	1.82		16.20	1+ , 6 , 1+	1.27	
40.72	1 , 4 , 1	0.	*s* .7 Aengstroms	12.70	1+ , 5 , 1+	1.34	
24.92	1 , 2 , 1	(1.25)		10.73	15 , 25 , 15	1.08	
23.93	3 , 7 , 5	.94		00.21	1+ , 6 , 1+	1.37	
18.79	2 , 3 , 1	1.31		4496.53	4 , 8 , 4	1.35	
06.41	1 , 3 , ..	—(1.35)		92.45	2 , 4 , 2	1.01	
05.92	6 , 10 , 5	(.98)		88.83	5 , 15 , 5	1.30	
00.35	1+ , 4 , 1	.88		87.67	6 , 10 , 6	1.45	
4694.67	1 , .. , 1	(1.45)		65.52	10 , 25 , 10	1.68	
94.25	4 , 10 , 3	.98		61.91	2 , 6 , 1+	1.18	
91.25	2+ , 8 , 3	1.37		61.28	2 , 10 , 1+	1.25	
51.76	6 , 12 , 5	1.12		55.20	1+ , 7 , 1	(1.00)	
40.26	1 , 3 , ..	—(.65)	*sb o*	54.62	2 , 7 , 1+	.90	
39.86	5 , 5 , 2	(1.23)	*sr o*	43.30	1+ , 5 , 1+	(1.28)	
31.94	4 , 12 , 4	.98		41.05	8 , 15 , 8	1.64	*b* wider than *r*
25.24	1 , 3 , 1	.99		36.20	1 , 2 , 1	(.99)	
09.53	2 , 6 , 2	.65		33.12	10 , 20 , 10	.95	
4589.31	1 , 3 , 1	(1.30)		27.85	1+ , 7 , 2	1.45	
81.78	1+ , 6 , 2	1.10		16.40	3 , 10 , 2+	.76	
66.85	1+ , 4 , 1	(1.02)		10.60	1 , 5 , 2	1.38	
63.48	8 , 12 , 6	1.19		08.61	1 , 2 , 1	(1.29)	
44.70	3 , 7 , 2	.83		00.56	1 , 3 , 1	(1.08)	
37.86	3 , 10 , 3	1.31		4399.25	4 , 10 , 3	1.09	
34.30	3 , 8 , 2	.65		98.10	3 , 8 , 4	.87	
33.50	6 , 12 , 5	1.46		96.67	2 , 6 , 2	.81	
32.47	3 , 8 , 2	.64		95.09	5 , 12 , 5	1.23	
29.67	1— , 3 , 1—	.—	Too weak	93.28	2 , 6 , 2+	1.27	
27.93	1 , 1+ , 1	.—	Too weak	91.30	30 , 50 , 30	1.43	
25.31	1 , 6 , 1	(1.14)	*sb o* broad	83.69	1+ , 5 , 1	1.28	

TABLE XVII—CONTINUED

λ	i	Δλ/λ²	Remarks	λ	i	Δλ/λ²	Remarks
4382.10	25 , 50 , 25	1.11		4313.17	5 , 7 , 3	1.42	
81.61	.. , 10 , 5	+1.14		07.40	2 , 5 , 1+	1.77	
78.34	1+ , 5 , 1+	1.11		06.57	1+ , 7 , 2	1.70	
77.50	2+ , 8 , 2+	1.14		00.98	1 , 3 , 1	(.78)	
75.77	1 , 5 , 1	1.12		4299.98	3 , 8 , 2	1.09	
74.96	6 , 15 , 6	1.11		98.80	3 , 8 , 5	.76	
67.12	1 , 4 , 1	1.18		91.95	1 , 5 , 1+	(1.12)	
66.08	2 , 5 , 2	1.74		90.52	1 , 4 , 1+	(1.14)	
62.55	1 , 4 , 1	(1.34)	*sb* broad	88.23	5 , 6	0.	*s* sharp center with background diffuse; in width .45 Aengstrom
61.50	6 , 10 , 4	1.15					
59.58	1+ , 4 , 1+	1.08					
58.70	2 , 8 , 2	1.12					
55.50	1 , 12 , 1	.86		86.90	2 , 4 , 2	1.17	
53.55	4 , 12 , 4	0.	*s* .45 Aengstroms	86.38	3 , 8 , 3	1.17	
51.64	1+ , 5 , 2	1.21		85.38	2 , 4 , 2	.72	
51.00	4 , 12	0.	*s* .45 Aengstroms	85.15	4 , 8 , 4	.86	
49.21	1+ , 3 , 1+	1.55		83.70	6 , 10 , 8	1.35	
48.73	2 , 4 , 2	1.08		83.25	1 , 3 , 1	(1.17)	
46.59	1+ , 5 , 2	1.07		74.51	2 , 4 , 2	1.15	
41.22	6 , 15 , 6	1.00		73.54	10 , 20 , 10	1.53	
38.30	1+ , 4 , 1	(1.00)		71.26	1+ , 1+ , 1	(.95)	
37.55	8 , 15 , 8	1.15		70.49	3 , 5 , 4	1.96	
36.70	1— , 3 , 1	(1.92)		64.52	1 , 3 , 1+	1.26	
35.89	8 , 20 , 8	1.21		64.23	1 , 2 , 1	(.78)	*sr o*
29.65	2 , 8 , 2	1.20		63.50	4 , 7 , 4	1.18	
20.77	2 , 10 , 2	(1.54)		62.90	1 , 4 , 1	(1.32)	
20.64	3 , 1 , 3		*s o*	61.64	1 , 3 , 2	(.86)	*sb o*
20.31	3 , 2 , 8	.23	*o*	61.38	2 , 1+ , 1	(.88)	*sr o*
18.71	3 , 8 , 2	.92		60.47	3 , 4 , 2	1.66	Broad
15.52	1 , 5 , 2	.85		57.58	2+ , 4 , 2	.76	

TABLE XVII—CONTINUED

λ	i	Δλ/λ²	REMARKS	λ	i	Δλ/λ²	REMARKS
4254.60	2 , 4 , —	(1.62)	This line and three following give by overlaps only five components	4214.15	1 , 1 , 1	(1.59)	
				13.21	2 , 4 , 1+	.79	
				11.60	4 , 8 , 4	1.18	
				11.05	2 , 6 , 2	.73	
				10.84	1 , 2 , 1	.71	
54.09	— , 4 , —	1.35		09.01	25 , 50 , 25	1.16	
54.00	— , 4 , —	(1.08)		06.83	2 , 5 , 2	1.31	
53.66	— , 4 , 3	(1.11)		4199.18	1 , 3 , 1+	2.05	
50.53	6 , 15 , 6	1.13		96.02	7 , 12 , 2	1.63	*sr o*
49.80	2 , 10 , 2	.78		95.72	3 , 10 , 4	1.35	
48.10	8 , 15 , 8	1.02		94.27	2 , 2 , 2	1.16	
44.05	3 , 10 , 3	1.26		93.15	4 , 5 , 3	1.11	
42.84	1 , 3 , 1+	(1.00)		92.03	4 , 5 , 2	1.20	
40.67	2 , 5 , 2	1.53		84.48	1+ , 3 , 2	.81	
35.12	2 , 2 , 1+	(1.09)	Weak *sr o*	79.86	8 , 15 , 6	1.25	
34.40	1 , 2 , 1—	(1.05)		74.59	1 , 2 , 1	(1.52)	
30.57	1 , 3 , 1	(1.38)		74.15	2 , 2 , 2	(1.83)	Prob. *sr* and *sb o*
27.49	1 , 3 , 1	(1.50)		73.70	2 , 2+ , 1	(1.35)	Prob. *sr o*
26.00	1 , 3 , 1	(1.59)		71.00	2 , 6 , 6	(1.20)	*sb o*
24.75	1 , 4 , 3	(1.22)	*sb o*	70.65	6 , 10 , 4	(1.23)	
24.37	3 , 6 , 2	(1.35)	*sr o*	67.45	1 , 3 , 1	(1.10)	
22.93	1 , 5 , 1	(1.00)		63.84	5 , 15 , 5	1.46	
22.65	1 , 2 , 1	(.98)		62.87	10 , 15 , 10	(1.43)	
20.23	4 , 8 , 4	1.12		59.82	5 , 12 , 5	1.32	
19.54	1— , 2 , 1	(.93)		56.69	10 , 25 , 12	(.60)	*sb o*
18.69	3 , 10 , 4	1.02		56.35	12 , 6 , 4	(.53)	*sr o*
18.34	2 , 8 , 2	(.80)	Diffuse	50.17	12 , 30 , 12	1.30	
16.19	2 , 5 , 3	(1.10)	*sb* either double or a weak line adjacent	42.63	6 , 20 , 4	1.08	
				41.82	3 , 10 , 4	1.12	See 40.42
				38.97	1+ , 3 , 2	1.11	

TABLE XVII—CONTINUED

λ	*i*	Δλ/λ²	REMARKS	λ	*i*	Δλ/λ²	REMARKS
4135.64	1 , 3 , 2	1.19		4073.15	1+ , 2 , 1+	(2.41)	*s*- diffuse
34.27	5 , 15 , 5	1.90		67.78	1 , 2 , 2	(1.98)	
30.44	1 , 2 , 1+	1.11		64.50	1 , 2 , 1	(.74)	
27.60	3 , 8 , 3	1.02		63.59	5 , 10 , 3	1.30	
22.06	1 , 5 , 2	1.27		59.66	3 , 5 , 3	1.29	
18.77	1 , 6 , 2	1.83		57.99	2 , 3 , 2	(1.30)	*sr o*
13.77	1+ , 4 , 2	1.18		57.52	3	(1.53)	*sr* and *sb o*
12.52	2 , 1+ , 2	1.63		57.23	1+ , 2 , 1	(.91)	*s*- broad, *sr o*
11.05	4 , 10 , 3	1.58	*sr* look double in 2d *O*	55.43	1+ , 5 , 1	(1.15)	
08.01	1 , 2 , 1	1.34		51.10	4 , 8 , 1	(1.33)	Probably *sr o* by 1.30
06.60	1 , 2 , 1	1.91		48.60	2 , 8 , 2	1.64	
06.14	3 , 10 , 3	1.28		48.18	1 , 3 , 1	(1.50)	
03.90	1 , 4 , 1	(1.16)	*sb o*	43.51	2 , 8 , 4	1.28	*sb o* 3.20
03.41	2 , 6 , 2	(1.42)	*sr o*	39.98	1+ , .. , 1+	(1.23)	*sb o*
01.60	1+ , 3 , 1+	1.85		39.53	1+ , 1 , 1	(1.47)	
01.08	8 , 12 , 8	1.23		37.40	2 , 6 , 2	1.08	
4099.13	5 , 12 , 5	1.36		36.71	8 , 15 , 8	.66	
97.93	1+ , .. , 1+	(1.35)	Sharp *sb o*	35.10	2 , 4 , 1	(1.73)	
97.52	1+ , 1 , 1+	(1.87)	Diffuse *sr o*	34.36	5 , 10 , 5	1.73	
91.53	3 , 3 , 1+	(1.75)	*sr o*	33.99	1− , 1+ , 1−	(1.16)	
89.35	1 , 3 , 3	(1.35)	*sb o*	32.82	1 , 8 , 5	(1.70)	*sb o sb* of 2.69
88.91	3 , 5 , 1	(1.20)	*sr o*	31.47	2 , 4 , 1+	1.20	
82.49	2 , 8 , 4	(1.01)	*sb o*	30.49	1 , 3 , 1	(.61)	
82.04	4 , 3 , 2	(1.69)	*sr o*	30.00	1 , 2 , 1	(.74)	
81.54	2 , 4 , 2	(1.92)		28.83	4 , 8 , 2	(1.27)	*sr o*
80.47	1 , 2 , 1	(1.04)		27.48	5 , 5 , 4	(1.30)	*sr* and *sb o*
79.77	2 , 2 , 2	1.24		26.30	4 , 12 , 3	(1.21)	*sr o*
74.84	2 , 4 , 2	1.21		25.78	6 , 12 , 7	.97	
73.92	1+ , 8 , 2	1.16		22.23	5 , 12 , 5	1.00	

TABLE XVII—CONTINUED

λ	*i*	Δλ/λ²	REMARKS	λ	*i*	Δλ/λ²	REMARKS
4018.27	1 , 3 , 1	1.35		3972.30	4 , 6 , 4	1.75	
16.02	1+ , 2 , 1+	1.18		69.70	2 , 7 , 2	(1.05)	*sb o*
13.34	1 , 3 , 1	1.20		69.47	2 , 3 , 2	(1.05)	*sr o*
12.67	8 , 20 , 6	1.44		67.37	1 , 2 , 1	(1.70)	
11.95	5 , 12 , 5	1.31		67.10	8 , 5 , 2	(.77)	*sr o* 7.52
09.26	5 , 10 , 5	1.18		66.34	1 , 2 , 1	(.91)	
08.35	2 , 5 , 2	2.09	*s*- are broad	62.49	1 , 5 , 2	1.22	
07.18	15 , 30 , 15	1.24		61.71	1+ , .. , 1+	(1.31)	
06.51	3 , 12 , 3	1.43		60.50	3 , .. , 3	1.37	
05.69	5 , 12 , 5	1.43	*s*- are broad	56.80	2 , .. , 2	.38	These two lines are not separated on *p*-plates, nor by Exner and Hascek.
03.49	6 , 20 , 8	.87		56.70	5 , 1 , 5	.76	
01.88	1+ , 3 , 2	1.16					
00.46	1 , .. , 1+	(1.02)					
00.10	1+ , .. , 1—	(1.18)					
3997.60	.. , 7 , 2	+1.29	*sr o*				
96.20	12 , 20 , 12	1.66		54.57	1 , 2 , 1	(1.11)	
94.70	12 , 30 , 12	.70		51.66	8 , 25 , 8	1.75	
94.49	.. , 3 , 2	+1.08		50.53	8 , 15 , 8	.96	
93.86	1— , .. , 1	(1.10)		49.06	10 , 15 , 8		
92.45	3 , 6 , 3	(1.34)	*sb o*	47.48	2 , 10 , 2	1.26	
92.21	3 , 1 , 2	(1.12)	*sr* and *sb o*	46.30	12 , 15 , ..	—	*o* by 5.96
91.89	2 , 5 , 1	(1.55)		42.20	2 , 7 , 2	1.16	
88.19	7 , 20 , 7	1.10	*sb o*	38.01	6 , 12 , 6	1.08	See quad. 37.14
87.88	.. , 4 , 2	+1.18		36.45	3 , 6 , 4	1.52	
86.81	1+ , 3 , 1+	.89		35.74	3 , 6 , 3	.69	
80.90	.. , 6 , 3	+ .97		35.32	1 , 4 , 1	(1.47)	
80.26	2 , 10 , 3	1.88		33.00	2 , 8 , 3	1.67	
76.56	5 , 15 , 5	1.76	*s*- are broad	32.35	3 , 8 , 5	(.84)	*sb o*
75.36	1+ , 5 , 1+	1.24		32.10	5 , 4 , 1	(.96)	*sr o*
73.36	2 , 8 , 1+	1.33		31.35	1 , 2 , 1—	(1.82)	*s* broad

TABLE XVII—CONTINUED

λ	i	Δλ/λ²	REMARKS
3927.54	4 , 10 , 4	1.27	
27.24	2 , 8 , 2	2.02	
25.19	5 , 10 , 5	1.30	
22.34	2 , 5 , 2	1.47	
21.53	1 , 2 , 2	1.41	
20.41	3 , 15 , 3	(1.91)*	Four lines here which overlap. Three are probably identical in separation.
19.19	2 , 6 , 3	(1.83)	
18.62	3 , 7 , 2	(1.79)	
18.13	2 , 7 , 8	(1.79)	
16.90	8 , 15 , 8	(1.26)	
14.60	1— , 3 , 1	1.52	
13.15	3 , 8 , 3	1.37	
11.45	1 , 1 , 1	(1.18)	
05.44	1 , 1 , 1	1.27	
05.29	8 , 12 , 8	1.42	
04.21	3 , 10 , 3	1.50	
00.99	10 , 10 , 8	(1.33)	*sr o* and *sb o*
3898.60	3 , 5 , 2	(1.11)	*sr o*
93.55	2 , 1 , 2+	(1.84)	*sb o*
93.17	2+ , 2 , 2	(1.24)	*sr o*
91.18	4 , 10 , 4	1.12	
87.54	1+ , 3 , 3	(1.82)	*sb o*
87.08	3 , 6 , 3	(1.29)	*sr o*
86.12	1+ , 2 , 1	(1.29)	*sr o*
84.96	8 , 15 , 8	1.09	*sb* wider than *sr*
84.67	3 , 5 , 3	1.06	
....	....	†	
3706.96	6 , 12 , 6	1.52	
....	....	†	
3705.16	2 , 6 , 2	.75	
04.92	— , 1 , 1	+(1.35)	
03.04	3 , 6 , 3	1.32	
....	....	†	
3696.82	2 , 5 , 2	1.09	
96.15	5 , 10 , 5	1.08	
92.71	2+ , 6 , 2+	1.18	
92.24	3 , 5 , 3	(1.09)	*sb o*
....	....	†	
88.93	10 , 20 , 10	1.50	
88.40	1— , 2 , 1+	(1.12)	*sb o*
88.15	1+ , 2 , 4	(1.19)	*sr* and *sb o*
87.13	1+ , 2 , 1	(1.10)	
83.50	1+ , 2 , 1—	(.61)	
82.06	2 , 4 , 2	(2.02)	
81.38	1+ , 3 , 1	(.89)	
79.89	12 , 20 , 12	1.72	
....	....	†	
75.72	8 , 15 , 8	1.12	
73.97	6 , 15 , 6	1.15	
71.72	2 , 4 , 2	1.21	*sr* wide, *sb* sharp
70.21	3 , 8 , 5	(1.78)	
68.31	1+ , 4 , 1	(.85)	
63.88	12 , 15 , 12	1.16	
61.74	2 , 7 , 1+	1.05	
57.70	1— , 2 , 1	(1.06)	
56.84	1 , 3 , 1—	(1.16)	

*On no-field there are two lines, 0.54 and 0.41, intensities 1 and 4 respectively. Probably run together *p*-. On *s*- there is a broad doublet symmetrical with 0.41.

†Lines omitted here appear in Table XIX.

TABLE XVII—CONTINUED

λ	*i*	Δλ/λ²	REMARKS
3652.69	5 , 15 , ..	—1.14	*sb o* 2.31 a quad. with same *s*-separation
51.72	1 , 3 , 1	(1.52)	
50.95	4 , 10 , 6	1.76	
49.37	12 , 25 , 12	.85	
48.55	3 , 5 , 3	1.20	
47.45	3 , 5 , 3	(1.59)	*sr o*
44.84	1+ , 3 , 1+	1.81	
44.48	1+ , 4 , 1+	1.37	
43.62	1 , 4 , 1	1.50	
41.74	1 , .. , 1	1.17	*p*- just off end of plate
38.42	1+ , .. , 1+	1.48	*p*- just off end of plate
37.68	2 , 5 , 2	1.66	*p*- broad
36.70	1+ , 5 , 1+	1.32	
36.05	5 , 8 , 3	1.03	*sr o* by 6.30
35.53	3 , 12 , 3	1.22	
35.40	2 , 8 , 3	1.83	
34.70	4 , 10 , 4	1.08	
34.34	1 , 5 , 1+	.96	
32.94	1 , 5 , 1	(1.20)	
32.74	1+ , 4 , 2	1.88	
29.36	1+ , 3 , 2	1.03	
26.05	6 , 10 , 12	(1.44)	*sb o*
25.74	12 , 15 , 8	(1.55)	*sr o*
25.20	2 , 2 , ..	—(1.15)	
25.05	3 , 12 , 3	(1.22)	*p*- not isolated from *p*- of 4.90

λ	*i*	Δλ/λ²	REMARKS
3624.90	8 , 12 , 3	(1.04)	
24.12	3 , 6 , 4	1.28	
19.85	1+ , 3 , 1+	(.82)	
18.48	1 , 4 , 1+	(1.31)	
17.22	12 , 15 , 12	(1.19)	*sb* probably *o* by 7.15 and 6.85
16.85	.. , 3 , 1+	+(1.33)	
15.47	1 , 2 , ..	—(1.00)	*sb* lost in 5.26
14.51	1 , 3 , ..	—(1.27)	*sb* lost in 4.16
13.91	.. , 4 , 3	+(1.39)	*sr o* by 4.16
13.02	1 , 2 , 1	(2.63)	
10.94	2 , 8 , 2	1.43	
10.55	2 , 8 , 2	1.28	
10.20	3 , 6 , 3	1.53	
09.60	20 , 25 , 20	1.22	
09.34	.. , 8 , 3	+ .96	
05.78	3 , 8 , 3	1.42	
04.17	3 , 8 , 2	1.52	
03.49	2 , 8 , ..	— 1.39	*sb o*
03.32	8 , 15 , 8	1.56	
01.20	10 , 25 , 10	1.20	
3599.86	1+ , 1 , 2+	(1.19)	*sr* and *sb o*
99.45	2 , 4 , 2	(1.66)	
95.72	1 , 3 , 3	(1.06)	*sb o*
95.40	3 , 5 , 3	(1.53)	*sr* and *sb o*
94.20	1 , 2 , 1	1.41	
93.96	7 , 10 , 7	1.65	
91.55	1 , 5 , 12	.90	
91.16	3 , 8 , 2	.88	
88.35	3 , 8 , 3	1.35	

TABLE XVII—CONTINUED

λ	i	Δλ/λ²	REMARKS	λ	i	Δλ/λ²	REMARKS
3585.16	5 , 8 , 3	.96		3550.47	3 , .. , 4	.92	p- o
84.28	3 , 5 , 3	1.39		47.60	2 , 4 , 1	(1.23)	
83.16	3 , 5 , 2	1.24		46.41	1 , .. , 2	(1.06)	p- not observed
81.57	1 , 1—, 3	(1.18)		46.13	2 , .. , 1	(1.51)	*sr o* 6.41
81.35	3 , 6 , 3	(1.31)		41.80	5 , 8 , 3	1.29	
80.36	4 , 10 , 4	1.75		39.75	12 , 30 , 20	(1.26)	
79.45	10 , 12 , 8	.98		39.37	20 , 15 , 8	(1.26)	
78.27	1+ , 4 , 1+	1.33		38.90	1+ , 6 , 1+	(1.06)	p- nearly the width of s- separation
77.34	1 , 3 , 1+	.72					
76.68	5 , 8 , 3	1.18					
75.43	12 , 15 , 12	1.07		38.37	1 , 5 , 1	(1.10)	s- interior all exposed s- very weak compared to p-. Same holds for 8.90
73.64	1 , 5 , ..	—(.98)					
73.35	6 , 10 , 4	1.55					
71.70	3 , 6 , 3	1.73					
70.21	1 , 5 , 3	— 1.33					
68.10	2 , 4 , 2	1.81					
67.83	2 , 6 , 2	.92		37.30	8 , 15 , 6	.76	
67.37	2 , 10 , 2	.69		36.80	1+ , 3 , 1	(.95)	
67.16	2 , 8 , 2	1.19		32.08	2 , 10 , 5	(1.11)	*sr o*
65.52	4 , 8 , 4	1.60		31.80	5 , 2 , 2	(1.02)	*sr* and *sb o*
65.24	1 , 1 , 1	(1.19)		31.61	2 , 4 , 1	(1.25)	*sb o*
64.83	4 , 6 , 4	1.16		30.72	1 , 5 , 1	(1.19)	
63.48	1 , 4 , 1	1.18		29.06	10 , 12 , 15	1.18	
61.87	2 , 3 , 2	1.14		22.09	10 , 15 , 10	1.38	
60.95	1 , 3 , 1	.95		15.89	1+ , 3 , 1	1.44	
60.08	8 , 15 , 8	1.13		15.13	2 , 4 , 1	1.46	
55.21	3 , 6 , 2	.94		10.91	1 , 2 , 1	1.20	
53.23	7 , 8 , 7	1.21		10.69	1 , 1 , 1	1.01	
52.03	1 , 3 , 1	(1.08)		07.72	3 , 5 , 2	1.03	
51.55	1 , 5 , 1	(1.34)		07.00	2 , 5 , 2	1.59	

TABLE XVII—CONTINUED

λ	i	Δλ/λ²	REMARKS	λ	i	Δλ/λ²	REMARKS
3505.62	5 , 8 , 5	1.20		3473.97	1— , 1 , 1—	(1.45)	
04.20	1— , 3 , 1—	(1.15)		69.50	1+ , 5 , 2	1.48	
03.75	5 , 6 , 3	1.29	Probably *o* by 3.93	68.36	8 , 15 , 10	1.10	
02.94	5 , 10 , 5	1.77		65.17	1 , 3 , 1	(1.83)	
01.61	5 , 8 , 4	1.29		64.58	1 , 3 , 1	(1.14)	
00.45	3 , 3 , 3	1.19		63.86	7 , 15 , 7	(1.21)	
3498.15	3 , 8 , 3	1.43		63.00	10 , 20 , 8	.76	
97.85	3 , 2 , 1	(1.36)	*sr o* by 8.15	61.37	4 , 8 , 3	.97	
97.19	3 , 5 , 2	(1.16)	*sr o* 7.41 which see	61.20	.. , 3 , 1+	+(1.28)	
			sb o 6.94	55.40	1 , 3 , 1	(1.48)	
96.94	1— , 1 , 1	(1.22)		53.68	1 , 3 , 1	(1.08)	
96.19	1— , 1 , 2	(1.42)	*sb o*	51.85	1+ , .. , 1+	(1.40)	
95.90	2 , 4 , 1	(1.38)	*sr o*	51.13	2 , 3 , 3	(1.33)	*sb o* 0.90
93.70	8 , 15 , 8	1.38		49.42	2 , 5 , 2	1.31	
93.43	1 , 3 , 1	1.14		45.34	5 , 8 , 4	1.30	
91.75	1+ , 3 , 1	1.24		44.15	1+ , 3 , 1+	1.25	
90.67	5 , 8 , 3	(1.56)	*sb o* and weaker	43.25	1 , 2 , 1	(.54)	*s*- are broad
90.42	3 , 5 , 4	(.90)	*sr o* and weaker	42.72	1 , 1+ , 1	(1.16)	
88.00	3 , 5 , 2	1.39		41.49	2 , 4 , 2	1.69	
87.15	1 , 4 , ..	—(1.31)	*sb o*	39.83	12 , 25 , 12	1.27	See 41.16
86.67	12 , 25 , 10	1.21	*sr o*	37.42	3 , 10 , 3	1.26	and 39.07
85.25	4 , 10 , 2	(.91)	*sr o*	37.13	1+ , 4 , 3	1.75	*sb o*
84.25	1+ , 4 , 1+	1.62		36.80	3 , 8 , 3	1.27	*sr o*
79.33	4 , 12 , 4	.66		36.05	15 , 30 , 15	1.51	
78.60	2 , 5 , 2	1.78		34.86	3 , 5 , 3	1.45	
78.28	3 , 8 , 3	1.18		31.95	4 , 8 , 4	1.48	
77.84	1 , 4 , 2	1.76		31.16	1 , 2 , 1	(1.24)	
76.70	5 , 7 , 5	1.14		30.03	4 , 6 , 4	.91	
75.71	1 , 2 , 1	1.14		29.53	3 , 4 , 3	1.18	
74.46	1 , 2 , 1	1.33		29.10	2 , 5 , 3	1.38	

TABLE XVII—CONTINUED

λ	i	Δλ/λ²	REMARKS	λ	i	Δλ/λ²	REMARKS
3426.04	4 , 5 , 3	1.19		3377.57	1 , 3 , 1	1.27	
23.24	3 , 6 , 2	.98		76.98	1+ , 3 , 1+	1.61	
22.75	1+ , 5 , 1+	1.32		75.12	2 , 4 , 1+	1.42	
21.34	8 , 15 , 6	(.98)		74.73	5 , 10 , 3	1.20	
18.89	6 , 12 , 5	.75		73.68	1 , 2 , 1—	1.19	
16.54	1 , 2 , 1	1.52		72.85	2 , 3 , 1	1.30	
16.03	1— , 2 , 1	(1.14)		71.96	6 , 10 , 6	1.30	
13.52	1 , 2 , 1	(2.43)		66.64	10 , 10 , 8	(1.37)	Prob. *sr o* by 6.87
13.15	3 , 5 , 2	1.43		63.20	2 , 4 , 1	1.27	
05.64	2 , 5 , 2	1.21		61.79	3 , 8 , 3	1.24	
04.75	5 , 8 , 5	1.38		60.54	3 , 5 , 5	(1.19)	
03.41	5 , 8 , 3	1.64		60.30	5 , 2 , 1+	(1.31)	
02.81	15 , 25 , 15	1.54		58.74	6 , 12 , 5	.69	
02.16	3 , 7 , 3	1.51		55.69	2 , 4 , 2	1.20	
01.78	1 , 5 , 3	(1.09)	*sr* diffuse	54.76	3 , 6 , 1	(.78)	
3398.70	4 , 8 , 3	1.27		54.35	8 , 12 , 10	1.13	*sb o*
98.02	1+ , 5 , 5	(1.25)	*sb o*	54.10	10 , 3 , 1+	(1.07)	*sr o*
97.65	5 , 8 , 3	(1.42)	*sr o*	51.38	15 , 30 , 15	1.38	
96.87	2 , 8 , 6	1.45	*sb o*	46.68	4 , 6 , 4	1.83	
96.62	6 , 8 , 3	1.39	*sr o*	45.01	3 , 6 , 3	1.10	
94.96	6 , 7 , 4	1.27	Prob. *sr o* by 5.26	43.77	6 , 8 , 4	1.25	
94.27	2 , 4 , 2	1.14		38.54	2 , 6 , 1	.61	See 38.00 6 comps.
93.38	2 , 4 , ..	—(1.10)	*sb o*	33.22	1+ , 3 , 1	1.46	
93.13	.. , 3 , 1+	+(1.07)	*sr o*	32.56	1 , 3 , 1+	1.55	
92.20	20 , 30 , 20	1.54		30.62	3 , 7 , 3	1.60	
90.54	2 , 3 , 1+	1.40		28.40	1— , 1 , 1—	(1.06)	
88.75	2 , 5 , 3	1.50		27.32	2 , 5 , 2	1.41	
85.66	10 , 15 , 10	.96		26.58	1 , 3 , 1	(.98)	
83.27	5 , 10 , 4	1.58		25.27	15 , 25 , 15	1.58	
81.03	1— , 2 , 1	(1.37)		21.57	8 , 15 , 8	1.32	

TABLE XVII—CONTINUED

λ	i	$\Delta\lambda/\lambda^2$	REMARKS	λ	i	$\Delta\lambda/\lambda^2$	REMARKS
3320.46	5, 8, 4	(1.08)		3265.73	1−, 3, 1	(1.23)	
17.90	1, .., 2	1.31		64.60	1, 4, 1	(1.45)	
14.99	5, 10, 4	1.78		59.76	1+, 5, 1+	(.97)	
13.82	2, 6, 2	1.49		56.38	8, 12, 8	1.33	
10.35	5, 7, 2	1.29	*sr o* by 10.65	55.62	2, 7, 2	1.08	
09.25	1+, 4, 1+	1.45		54.95	1+, 4, 1+	(.91)	
04.33	4, 8, 4	1.64		52.85	2, 3, 1	(1.25)	*sr o*
01.81	2, 4, ..	−(1.48)	*sr* in shadow of 1.44	52.02	1, 3, 1−	(1.22)	
01.44	6, 8, 5	1.25		49.02	2, 2, 2	1.53	
00.63	.., 3, 1	+(1.00)	*sr o*	41.25	.., 7, 3	+(1.61)	
3299.80	1, 2, 1	(.99)		39.38	1, 3, 1−	(1.18)	
97.95	5, 10, 4	1.31		38.23	8, 12, 8	(1.16)	
97.47	1+, 4, 1+	1.25		35.95	6, 8, 6	1.68	
96.72	4, 8, 4	1.27		33.70	1−, 1−, 1−	(1.63)	
95.12	.., 6, 2	+(.64)		32.16	3, 2, 2	1.46	
94.37	2, 4, 7	1.63	*sb o*	30.98	3, 5, 2	1.04	
94.06	7, 8, 5	(1.63)	*sr o* and *sb* in shadow of 3.71	29.10	8, 15, 8	.87	
93.71	.., 5, 2	+(1.33)		27.90	1, 3, 1−	1.46	
92.62	10, 20, 8	1.11		26.52	1, 2, 3	(2.19)	*sb o*
91.88	12, 30, 15	1.81		26.23	3, 2, 1	(1.21)	*sr o*
90.73	3, 4, 2	1.07		25.80	1, 2, 1	(1.37)	
88.27	2, 2, 1	1.48		21.40	6, 12, 8	1.31	
87.90	7, 12, 7	1.36		20.46	1+, 3, 1+	1.41	
83.11	2, 5, 1+	1.15		17.89	1, 2, 3	(1.79)	*sb o*
82.75	1+, 4, 2	1.15		17.61	3, 4, 2	(1.02)	*sr o*
80.52	2, 5, 1+	1.06		16.67	1, 3, 1	(1.49)	
75.20	6, .., 5	1.83	*p*- is *o*	10.43	3, .., 3	1.15	These three lines have diffuse *p*-components
69.60	1, 4, 1	(1.61)		08.15	2, .., 2	1.44	

TABLE XVII—CONCLUDED

λ	*i*	Δλ/λ²	REMARKS	λ	*i*	Δλ/λ²	REMARKS
3207.88	1+ , .. , 1+	(1.74)		3134.50	2 , 4 , 2	1.41	
3198.83	1 , 3 , 3	(1.27)	These four lines give but five components, all of which are sharp, on the *s*-plates	25.60	6 , 12 , 8	(1.46)	
				25.27	8 , 6 , 2	(1.81)	
				23.05	5 , 8 , 4	1.62	
				19.60	8 , 15 , 6	1.12	
				08.37	8 , 15 , 7	1.31	
98.57	3 , 4 , 2	(1.48)		05.83	5 , 8 , 4	1.10	
98.33	2 , 2 , 2	(1.30)		01.02	3 , 7 , 3	1.14	
98.09	3 , 4 , 2	(1.35)		3088.54	3 , 5 , 2	1.17	
91.23	1+ , 3 , 1+	(.98)		80.31	6 , 8 , 5	1.15	
88.29	10 , 12 , 8	1.53		78.91	4 , 8 , 4	1.16	
85.05	4 , 7 , 4	1.28		72.22	4 , 8 , 3	1.55	
82.80	1 , 2 , 1+	1.71		67.81	4 , 10 , 3	.99	
81.33	1+ , 4 , 1+	1.18		34.17	1 , 4 , 1	(1.17)	This and subsequent lines measured in second order only
80.35	10 , 20 , 10	1.17					
79.18	5 , 8 , 5	1.02					
75.84	6 , 10 , 4	1.11					
69.43	1 , 2 , 1	(1.90)					
67.66	1— , 3 , 1—	(1.22)		2988.33	1+ , 5 , 1+	.83	
66.92	1+ , 2 , 1+	(1.12)		42.97	2 , 5 , 2	1.61	
65.94	1+ , 2 , 1+	1.62		28.30	1 , 3 , 1	(1.34)	Many weak triplets are visible as far as 2750. But other types are not present
64.60	1— , 3 , 1	(1.24)					
62.95	1 , 3 , 1+	(1.39)					
54.89	6 , 8 , 6	.85					
54.40	3 , 6 , 2	1.27					
51.74	1— , 3 , 1—	(1.23)		25.06	1 , 5 , 1	(1.21)	
42.95	5 , 7 , 4	1.21		2887.90	2 , 5 , 2	1.23	
41.95	1+ , 4 , 1+	(1.50)		85.13	2 , 4 , 1+	1.09	
39.38	5 , 8 , 5	1.67	*s*- are broad	84.38	1+ , 3 , 1+	(1.02)	

which have a separation of 1.07 to 1.08. Do these belong to the normal triplet whose separation is 1.105 or are they a class by themselves? I selected some of the sharpest and easiest measured of these lines and subjected them to renewed measurements upon plates of both field-strengths, and was not able to change their value. I similarly treated a few lines with separations about 1.04, 1.14, and 1.18 with a similar result. The whole could be answered satisfactorily with five times the accuracy in measurement.

There is a characteristic of these triplets that is impressive. One may choose a line with almost any magnitude of separation, and not far from it find one or more lines which have practically identical separation. The following seven lines lie in a small bundle upon the plates. Four of these and possibly six are duplicates. These lines are λ 4383.69 to 4374.96 inclusive (see table). There is another bundle between λ 4286.90 and 4283.25 with three lines alike. The photographic plates suggest many such bundles or groups. Naturally other types than triplets may be present in these bundles. These at once suggest those recurring groups in those substances in which series have been found. This fact, together with the numerous close companions having like separations, would suggest that hope for relationship among the thorium lines was not forlorn.

Table XVIII is a list of unsymmetrical triplets not included in Table XIX. Stronger exposure may reveal other components for λ 3294.76. The line as recorded is uncommon rather than unsymmetrical. The *s*- component is in the zero position and the *p*-components separated.

Table XIX contains a list of lines in a very small portion of the spectrum. The spark spectra were obtained from thorium chloride upon carbon electrodes. About λ 3885, a carbon band begins, whose lines are troublesome for some distance. As usual, I was omitting these lines of zero separation, but found that I was omitting many lines from Exner and Haschek's tables. Close measurement of some of these unseparated lines showed that they agreed so closely with the tabulated wave-lengths which I was omitting that there could be no doubt as to their identity. Those which were found separated were unsymmetrical. Unseparated lines are supposed to

arise from compounds. The carbon band lines which are unseparated are attributed to cyanogen. A few of the lines in this region Exner and Haschek mark cyanogen. However, all but one of these show separation. Many not attributed to cyanogen fail to show any separation whatsoever. These may be due to compounds, but it is

TABLE XVIII

λ 4107.58		λ 4112.95		λ 4110.72	
i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$	i	$\Delta\lambda/\lambda^2$
2......	$-(1.16)$ *s*	1.....	$-(1.15)$ *s*	2.....	-1.24 *s*
4......	$-(\ .12)$ *p*	3......	$+(\ .13)$ *p*	8.....	$+\ .27$ *p*
2......	$+(1.16)$ *s*	1......	$+(1.15)$ *s*	3.....	$+1.87$ *s*

λ 3294.76	
i	$\Delta\lambda/\lambda^2$
1+....	$-(\ .77)$ *p*
2......	0 00 *s*
2......	$+(\ .77)$ *p*

only conjectural. Their behavior is generally very peculiar. In my study of zirconium I noted that most of the lines of zero separation looked like unresolved types, which would probably separate with stronger field. The unresolved lines of thorium have generally a different appearance, and most of them are probably of an unseparable type. There are a few distributed through the spectrum, but the most of them are found in the small region of Table XIX.

Comparison of the intensities of the *s*- and *p*- components with the corresponding no-field lines showed that there was no uniformity in their ratio to the intensities of no-field lines, and therefore no uniformity in their ratio to each other. It is a well-known fact that the exposure of the plates must be many times longer when the spark is in the magnetic field. Possibly, it is equally well known that the relative intensities of the lines change. This is attributed to the change in the character of the spark. In the simplest theory

TABLE .IX

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3875.85	2	1, 4		−2.10	....	+1.07	....	....	....	Probably *sr o*, then unsym.
75.56	2	3, 2		1.26	....	.26 .88	....	....	....	
75.00	8	2, 8	20	1.37	....	1.00	....	0	....	
74.35	3	1, 5—	6	1.35	....	.66	— .23	....	....	
73.94	10	4, 3	15	....	±1.04	....	....	0	....	
73.56	3	2, 1	5, 1	.66	....	1.30	.31	....	+ .96	Quadruplet unsymmetrical
72.87	10	10, 12	20	....	1.30	....	....	0	....	
72.51	..	3	1	....	....	1.32	....	0	....	*sr o* symmetrical
....	..	..	5	....	?	....	....	±1.15	....	
70.30	1	6	4	.23	....	....	....	0	....	
70.13	2	3	3	....	....	.23	....	0	....	
69.85	1	5	7	....	0	....	....	0	....	
69.54	2	5	5	.26	....	....	....	0	....	
68.23	1	3	2	....	0	....	....	0	....	
68.13	3	..	2	....	....	....	....	0	...	
68.04	2	3	3	.23	....	....	....	....	.53	
67.77	2	3	3	.69	....	....	.60	....	....	
67.42	1	1	3, 1+	....	.38	....	.42	....	1.32	
67.02	8	6, 5	7	1.02	....	.52	....	0	....	
66.63	1—	2	2	....	0	....	....	0	....	
66.21	4	7, 3	3, 6	....	....	....	....	....	....	Quadruplet unsymmetrical
65.72	1	2	2	....	0	....	....	0	....	
65.54	..	1	2	....	0	....	....	0	....	
65.33	1	4	..	....	0	....	....	....	....	
65.14	1	..	..	....	....	....	....	....	....	
65.00	..	1	1—	....	0	....	....	0	....	
64.67	1	8	6	....	0	...	....	0	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3864.47	2	3	3	....	o	....	....	o	....	
64.27	1	3	2	....	o	....	....	o	....	
63.54	15	15, 10	10, 20	−.93	....	+1.55	−.13	....	o	*p*, broad
62.52	6	7, 3	15	....	±.75	....	....	o	....	Probably *sr o*
61.86	1	5	4	....	o	....	....	o	....	
61.69	5	5	12	....	o	....	....	o	....	
61.28	1—	1	2	....	o	....	....	o	....	
60.96	1—	1+	2	....	o	....	....	o	....	
60.76	2	5	7	....	o	....	....	o	....	
59.98	25	..	..	....	....	....	....	....	....	Quadruplet symmetrical
59.43	1	2	3	....	o	....	....	o	....	
59.03	2	2	2	....	o	....	....	o	....	
58.30	..	1	1	....	o	....	....	o	....	
57.98	1	2	2	....	o	....	....	o	....	
57 77	1	2	2	....	o	....	....	o	....	
57.57	1+	1—	2	....	o	....	....	o	....	
57.47	1	..	..	....	....	....	....	....	....	
57.37	..	..	..	....	....	....	....	....	....	No-f, *p* and *s* look double
57.21	1	4	3	....	o	....	....	o	....	
57.02	1—	1	1—	....	o	....	....	o	....	
56.77	3	5	5	....	o	....	....	o	....	
56.45	4	5	2	....	o	....	....	o	....	
56.23	1	..	..	....	....	....	....	....	....	
55.90	1	3	2	....	o	....	....	o	....	
55.73	1	5	6	....	o	....	....	o	....	
55.47	..	1	1	....	o	....	....	o	....	
55.13	..	..	1	....	o	....	....	o	....	
54.97	3	2	8	....	o	....	....	o	....	

TABLE XIX—CONTINUED

λ	Intensities			$\Delta\lambda/\lambda^2$						Remarks
	No-f	s-	p-	s-			p-			
3854.61	25	15, 12	25	−1.08	....	+1.78	....	0	....	
54.21	1−	1	1+	....	0	....	....	0	....	
53.95	1	1	1	....	0	....	....	0	....	
53.60	2	5	6	....	0	....	....	0	....	
53.07	3	2	5	....	±1.59	....	....	0	....	
52.88	1−	..	2	....	....	....	....	0	....	
52.59	2	5	7	....	0	....	....	0	....	
52.27	4	1	3	....	0	....	....	0	....	
52.00	1−	1−	1−	....	0	....	....	0	....	
51.72	1+	3	3	....	0	....	....	0	....	
51.36	2	2	4	....	0	....	....	0	....	
51.24	2	1	..	....	0	....	....	....	....	
51.09	1	2	..	....	0	....	....	....	....	
50.93	2	2	..	....	0	....	....	....	....	
50.74	1	1−	..	....	0	....	....	....	....	
50.56	1	1	..	....	0	....	....	....	....	
50.39	1	1	3	....	0	....	....	0	....	
50.23	5	3	10	....	0	....	....	0	....	
50.06	1	3	2	....	0	....	....	0	....	
49.83	1	2	2	....	0	....	....	0	....	
49.43	1	5	3	....	0	....	....	0	....	
49.07	2	8	12	....	0	....	....	0	....	
48.93	1−	1	3	....	0	....	....	0	....	
48.73	1	2	1, 1	....	0	....	....	....	....	p- is doublet.
48.34	1−	2	2	....	0	....	....	0	....	
48.02	2	6	6	....	0	....	....	0	....	
47.43	..	2	2	....	0	....	....	0	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3847.16	..	..	..	....	....	....	....	....	....	Not on no-f; mixed with 7.02; latter unsymmetrical
47.02	..	..	..	....	....	....	....	....	....	
46.40	2	6	8	....	±1.20	....	....	0	....	
46.16	1	..	2	....	....	....	....	0	....	
45.68	3	8	8	....	0	....	....	0	....	
45.16	2	6	6	....	0	....	....	0	....	
44.81	..	1	1	....	0	....	....	0	....	
44.37	3	8	7	....	0	....	....	0	....	
44.18	1	2	2	....	0	....	....	0	....	
43.57	2	2	3	....	0	....	....	0	....	
43.09	6	8	12	—.19	....	....	....	....	+.19	Quadruplet unsymmetrical
42.69	..	..	..	....	....	....	....	....	....	5 components symmetrical
42.10	..	..	..	....	....	....	....	....	....	
41.87	1	..	3	....	....	....	....	0	....	
41.14	1—	1—	4	....	0	....	....	0	....	
40.99	3	..	1	....	....	....	....	0	....	
40.61	3	6	7	....	0	....	....	0	....	
39.90	15	15	30	....	±1.38	....	....	0	....	Triplet symmetrical
39.56	2	?	3	....	±1.60	....	....	0	....	Triplet symmetrical
39.33	2	7	5	....	0	....	....	0	....	
38.87	1	..	2, 2	....	....	....	—.39	....	+.24	Exner's line is 8.92, agreeing with *pr*
38.49	1	2	2	....	0	....	....	0	....	
38.01	?	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
37.76	1	3	2	....	0	....	....	0	....	
37.50	1	2	2	....	0	....	....	0	....	
36.65	10	3, 10	15	—1.30	....	+.66	....	0	....	
36.19	1	2	1	....	0	....	....	0	....	

TABLE XIX—CONTINUED

λ	Intensities			$\Delta\lambda/\lambda^2$						Remarks
	No-f	s-	p-	s-			p-			
3836.08	1—	1	1—	....	o	....	....	o	....	
35.83	1	2	1	....	o	....	....	o	....	
35.45	3	3	3	....	o	....	....	o	....	
35.21	2	5	5	....	o	....	....	o	....	
34.60	1—	2	1+	....	o	....	....	....	+ .48	
34.27	2	2	4	....	o	....	....	o	....	
33.83	2	6	4	....	o	....	....	o	....	
33.10	3	..	6	....	....	....	....	o	....	
32.87	..	..	..	....	....	....	....	....	....	Quadruplet weak
32.59	2	4	5	....	o	....	....	o	....	
31.90	10	8, 5	20	.86	....	1.62	....	o	....	
31.12	2	1—	3, ..	....	o	....	— .63	....	....	
30.93	5	5	7	....	±1.64	....	....	o	....	
30.70	..	..	..	....	....	....	....	....	....	Quadruplet
30.27	3	1—	2	....	o	....	....	o	....	
30.05	1	..	1—	....	....	....	....	o	....	
29.81	1+	4	3	.27	....	....	....	o	....	
29.61	4	5	7	....	o	....	....	o	....	
28.58	5	..	..	....	....	....	....	....	....	6 components unsymmetrical
28.30	1	..	..	....	....	....	....	....	....	
27.92	1—	1	1—	....	o	....	....	o	....	
27.69	..	..	2	....	....	....	....	o	....	*p*- possibly doublet
27.46	..	..	2	....	....	....	....	o	....	
27.07	..	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
26.86	1+	5	3	....	o	..	....	o	....	
26.44	3	.., 4	.., 2	....	....	1.60	....	....	.52	No *r*-components found
26.10	2	..	2	....	....	....	....	o	....	
25.87	1	4	2	....	o	....	....	o	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3825.44	1	..	2	....	0	....	....	0	....	
25.33	2	2, 1	3	....	±1.08	....	....	0	....	
25.25	3	2+, 2	8	....	1.08	....	....	0	....	
24.96	1—	..	2	....	....	....	....	0	....	
24.70	1—	..	2	....	....	....	....	0	....	
24.52	1	5	2	....	0	....	....	0	....	
24.26	1	1	1	....	0	....	....	0	....	
23.99	1	2	4	....	0	....	....	0	....	
23.76	3	.., 4	8	....	....	....	....	0	....	*sr o*, therefore unsymmetrical
23.47	1	..	4	....	....	....	....	0	....	
23.22	3	5	1	....	0	....	....	0	....	
23.06	2	1	3	....	0	....	....	0	....	
22.46	1	..	6	....	....	....	....	0	....	
22.33	..	..	..	....	....	....	....	....	....	5 components unsymmetrical
21.92	2	4	3	....	0	....	....	0	....	*p*- possibly doublet
21.57	..	..	..	....	....	....	....	....	....	Quadruplet symmetrical
20.92	4	4	6	....	0	....	....	0	....	
20.54	2	2	6	....	.88	....	....	0	....	
20.09	2	1—, 2	3	— .93	....	+ .69	....	0	....	*sr* sharp, *sb dr* broad, *p*- diffuse
19.44	2	2, 6	6	.82	....	.55	....	....	+ .22	
19.25	1	1—, 3	3	1.07	....	.43	....	0	....	
18.81	2	1+	2	....	0	...	....	0	....	
18.33	1	1+	2	....	0	....	....	0	....	*p*- *db* no-f broad, diffuse
17.82	1	8	5	....	0	....	....	0	....	
17.64	3	1—	2	....	0	....	....	0	....	
17.51	2	8, 1, 1, 4	8	....	....	....	....	0	....	*sb* at distance 2.05 which makes *sr* coincide with 7.82; for inner pair *sr* falls on 7.64

TABLE XIX CONTINUED

λ	Intensities			$\Delta\lambda/\lambda^2$						Remarks
	No-f	s-	p-	s-			p-			
3817.25	1	3	..	....	o	....	....	o	....	
17.12	..	1	1	....	o	....	....	o	....	Not present on no-f and s- and p-
16.96	1	..	..	....	....	....	....	....	....	not present for next line. Are these then all one line?
16.70	2	1	4	....	o	....	....	o	....	
16.29	3	6	8	....	o	....	....	o	....	
15.95	..	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
15.68	3	.., 3	.., 2	....	....	+1.03	....	....	+.76	If r-components are present they are too weak or overlap 5.95 and then unsymmetrical
15.16	5	2, 5	8	—.92	....	.43	....	o	....	sb falls on 4.99
14.99	1	5 ?	3	....	o	....	....	o	....	
14.87	2	..	7	....	o	....	....	o	....	s probably double, o 4.99 and 4.73
14.73	1	5	7	....	o	....	....	o	....	
14.12	2	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
14.08	2	3	2	....	o	....	....	±.67	....	Triplet with null s-
13.79	4	.., 1	3, 1	....	....	....	....	....	....	Quadruplet unsymmetrical
13.52	1	3, ..	1	.85	....	....	....	o	....	
13.21	20	15	30	....	±1.17	....	....	o	....	Triplet symmetrical
12.52	2	1—, 1—	2	....	....	....	....	o	....	Triplet symmetrical
12.16	1—	2	2	....	o	....	....	o	....	
11.79	2	5	5	....	o	....	....	o	....	
11.50	3	4	8	....	o	....	....	o	....	
11.10	5	1	5	....	....	....	....	o	....	Possibly s- is triplet, as a weak line to r is present
10.83	1	3, ..	1	.87	....	....	—.20	....	....	
10.70	2	2	3	....	o	....	....	....	.17	
10.00	8	5, 8	20	1.71	....	.84	....	o	....	No-f line double

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3809.62	1—	1	1	....	o	....	....	o	....	
09.28	2	3	3	....	o	....	....	o	....	
08.80	1—	1+	1+	—.31	....	....	....	....	+.26	
08.43	1—	1	1	....	±.57	....	....	o	....	*p* very broad. Probably 2 or 3 comps. A *p*-comp. in position 8.30 *s*- *d* inside, *d* outside. *p*- has pos. an external pair of components
08.04	5	15	8	....	1.55	....	....	o	....	
07.38	2	2+	3	....	o	....	....	o	....	
06.96	2	5	4	....	o	....	....	o	....	
06.48	7	5	3	....	o	....	....	o	....	
06.25	1	5	..	....	o	....	....	o	....	*p*- *o pr* of 6.12, therefore displaced to blue
06.12	6	5	8, 4	....	o	....	—.66	....	.86	*p*- called a doublet *o* 6.25 and 5.95
05.95	2	8	4	....	o	....	....	o	....	
05.73	5	4	1	....	o	....	....	o	....	
05.55	3	1, 1—	5	....	1.18	....	....	o	....	Triplet symmetrical
05.18	2	1—, 1—	2	....	1.93	....	....	o	....	Triplet symmetrical
04.85	3	..	6	....	....	....	....	o	....	
04.34	1	2	2	....	o	....	....	o	....	Blurred with next line on *p*- plate
04.19	2	..	2	....	....	....	....	o	....	*s*- absent and taken as a doublet *o* 4.34 and 4.01
04.11	1	2	..	....	o	....	....	....	....	
03.25	8	5, 3	12	....	.84	....	....	o	....	*s*- probably unsymmetrical, but no-f line not sharp enough to make the measurement
03.93	1—	2	1	....	o	....	....	o	....	
02.65	1	1, 1	1, 1	....	....	....	....	....	....	Quadruplet symmetrical *p*=*s*
02.31	3	..	..	....	....	....	....	....	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3802.10	2	3	3	....	o	....	....	o	....	
01.75	2	3	4	....	o	....	....	o	....	
01.61	3	2, 5	6	—1.28	....	+.64	....	....	+.37	p- is blurred with an adjacent b line. The latter symmetrical with no-f line 1.53
01.53	1	..	1	....	....	....	....	o	....	
00.80	3	4, ..	6	1.20	....	....	....	o	....	
00.53	4	..	5	....	....	....	....	o	....	p- diffuse, possibly doublet. No s- visible. If *sr o* 0.80 then *sb* should be visible
00.37	2	..	..	....	....	....	....	....	....	
00.23	1—	3	4	....	....	1.48	....	o	....	
3799.79	1	5	2	....	o	....	—.20	....	....	Exposure from this line past the next two on p- plate
99.65	1—	..	..	....	....	....	....	....	....	
99.36	1	..	1+	....	....	....	....	o	....	
98.77	1—	3	1—	....	o	....	....	o	....	
98.66	2	5	2	....	o	..	....	o	....	
98.25	3	2	6	1.45	....	1.82	....	o	....	
98.12	1—	..	3	....	....	....	....	o	....	
97.66	3	2, 5	8	1.41	....	2.25	....	o	....	*sb* is here assumed to *o* 7.37
97.37	2	5	1	....	o	....	....	o	....	
97.13	1—	4	4	....	o	....	....	o	....	
96.85	3	.., 1	1+	....	....	1.50	....	o	....	If *sr o* 7.13, then its sep. =2.37 approx.
96.33	1	3	3	....	o	....	....	o	....	
95.90	1—	1+	1+	....	o	....	....	o	....	
95.53	3	2, 5	5	1.09	....	.74	....	o	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3795.20	1—	1	1	....	o	....	....	o	....	
94.85	3	1—, 1	1	....	±1.20	....	....	o	....	
94.50	2	5	4	—.48	....	....	—.47	....	....	p- broad, possibly doub. or triplet
94.30	4	4	8	....	1.05	....	....	o	....	
93.95	2	..	3	....	(1.20)	....	....	o	....	Triplet symmetrical
93.65	2	..	3	....	(1.46)	....	....	o	....	s- components o
93.28	1	1—	1—	....	o	....	....	o	....	s- components o
93.11	1—	1—	2	....	o	....	....	o	....	
92.88	2	.., 2	2	....	....	+1.18	....	o	....	
92.52	6	..	..	....	....	....	....	....	....	
92.15	2	.., 1	3	....	....	1.50	....	o	....	7 components symmetrical
91.66	1—	..	..	....	....	....	....	....	....	
91.50	5	6, 4	10	....	1.06	....	....	o	....	p dr, sr o symmetrical; s- has diffuse background
90.99	8	6	10	....	o	....	....	o	....	
90.67	1—	1—	2	....	o	....	....	o	....	
90.51	3	2, 2	2	....	1.27	....	....	o	....	
90.26	2	2, 5	6	....	.84	....	....	o	....	
90.10	1	5, 1+	.., 2	....	....	....	....	....	....	sb o 90.10; p- possibly doublet
89.29	15	15, 20	25	....	1.30	....	....	o	....	Quadruplet unsymmetrical
88.66	1—	1	2	....	o	....	....	o	....	s- too broad to measure for dissymmetry
88.54	3	1+, 1	1	....	1.15	....	....	o	....	No-f diffuse, s and p- are sharp
87.80	1—	1	1—	....	o	....	....	o	....	p- diffuse; others sharp
87.65	1	..	2	....	o	....	....	o	....	
87.34	2	7	7	....	o	....	....	o	....	
87.04	3	1, 2	8	1.42	....	1.13	....	o	....	No-f broad
86.12	3	3, ..	8	1.32	....	....	....	o	....	sb o

TABLE XIX—CONTINUED

λ	Intensities			$\Delta\lambda/\lambda^2$						Remarks
	No-f	*s*-	*p*-	*s*-			*p*-			
3785.80	15	..	..	....	....	....	....	....	....	Quadruplet
85.50	1	..	..	....	....	....	....	....	....	
84.74	1	1—, 1	1+	....	....	....	....	o	....	
83.95	1	3	3	....	o	....	....	o	....	No-f diffuse
83.83	2	..	5	....	....	....	....	o	....	Region covering this and next two lines all exposed on *s*- plate
83.68	1—	..	..	....	....	....	....	o	....	
83.48	5	..	2	....	....	....	....	o	....	*p*- broad enough for three lines
83.15	5	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
82.35	1	2	1	....	o	....	....	o	....	
81.83	1—	5	3	....	o	....	....	o	....	
81.50	2	1, 1+	1—	— .97	....	+1.77	....	o	....	*sb o*
81.43	3	1+, 2	3	1.06	....	1.58	....	o	....	
80.65	1—	3	3	....	o	....	....	o	....	
79.95	1	5	3	....	o	....	....	o	....	
78.98	2	6	6	....	o	....	....	o	....	No-f is sharp; *p*- and *s*- are fuzzy
78.00	1	3, 1	2, 1	....	....	....	....	....	....	Quadruplet unsymmetrical
77.60	1	1+	1—	....	o	....	....	o	....	
77.27	1—	3	1	....	o	....	....	o	....	
76.80	1	1—, 1	1+	....	....	....	....	o	....	
76.43	4	2	3	....	±1.21	....	....	o	....	Triplet symmetrical
76.10	3	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
75.47	1	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
74.88	2	1—, 1—	1	....	....	....	....	o	....	Triplet too weak
74.40	5	6	12	....	1.12	....	....	o	....	
73.94	8	6, 8	15	....	....	....	....	....	....	Quadruplet symmetrical
73.23	1	2	3	....	1.21	....	....	o	....	Triplet symmetrical
72.83	1+	..	1	....	....	....	....	o	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3772.41	3	5, 3	6	— .94	....	+1.86	....	o	....	
71.80	2	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
71.55	8	3	6	....	±1.67	....	....	o	....	Triplet symmetrical
70.40	1—	..	..	....	....	....	....	....	....	
70.25	8	..	..	....	....	....	....	....	....	Quadruplet unsymmetrical
69.80	2	2, 1+	1	1.09	....	1.20	....	o	....	
68.62	2	3, 4	5	1.20	....	1.49	....	o	....	
68.05	12	6, 8	25	....	1.22	....	....	o	....	Triplet symmetrical
67.69	1—	..	1	....	....	....	....	o	....	
67.39	3	3	6	....	o	....	....	o	....	
66.65	1+	1—	1+	....	o	....	....	o	....	
65.57	1	6	2, ..	....	o	....	—1.03	....	....	*pb* lost in next line or too weak, probably unsymmetrical
65.43	8	3	12	....	1.25	....	....	o	....	Symmetrical triplet
64.80	1—	.. ..	1	....	....	....	....	o	....	There are two weak *sr* lines and no *sb* lines. These two may belong to another line.
64.48	1—	3	1+	....	o	....	....	o	....	
64.26	1	..	1	....	....	....	....	....	....	
64.01	1	1	1	.81	....	.98	....	o	....	
63.75	1+	1, 1—	3	1.22	....	....	....	o	....	
63.49	3	3	3	.98	....	....	....	o	....	*s*- sharp, *p*- broad, s^b not found
63.04	15	15	20	....	....	....	....	....	....	Quadruplet symmetrical
62.50	1—	2	2	....	o	....	....	o	....	
62.05	1—	..	1—	....	....	....	....	o	....	
61.91	1	..	..	....	....	....	....	....	....	
61.69	4	1—	3	....	....	....	....	o	....	
61.50	1	4	2	....	o	....	....	o	....	*s*, if present, is *o* by *sr* of 1.28

TABLE XIX CONTINUED

λ	Intensities			$\Delta\lambda/\lambda^2$						Remarks
	No-f	*s*-	*p*-	*s*-			*p*-			
3761.28	4	4, 6	10	—1.87	....	+1.30	....	0	....	
60.48	2	2, 1—	5	.49	....	2.42	....	0	....	*sb* may belong to another line
59.61	2	3	2	....	0	....	....	0	....	*p*- diffuse
59.46	5	3, 5	5	1.47	....	1.06	....	0	....	*sr o*
58.64	3	2	3	....	±.99	....	....	0	....	Symmetrical triplet
58.39	2	1	3	....	1.13	....	....	0	....	Symmetrical triplet *o* 8.64
57.88	6	3	8	....	.96	....	....	0	....	Symmetrical triplet
57.47	1	..	1	....	....	....	....	0	....	
56.93	1—	..	1	....	....	....	....	0	....	
56.36	3	1+	5	....	0	....	....	0	....	
56.17	2	..	1	....	....	....	....	0	....	
55.37	3	3	6	....	1.45	....	....	0	....	Symmetrical triplet
54.73	5	5, 3	10	....	.76	....	....	0	....	Symmetrical triplet
54.17	4	2, 1—	2	2.16	....	3.59	....	0	....	Possibly these *s*- components do not belong to this line
53.42	2	1 +	2	....	0	....	....	0	....	*p*- diffuse
52.73	20	20	40	....	1.43	....	....	0	....	Symmetrical triplet. *p*- broad but not resolved in second order
51.91	1	1, 1, ..	2	....	....	....	....	0	....	
51.22	2	1	2	....	.33	....	—.22	....	....	*s*- diffuse. No-f broad
50.82	1—	1	3	....	....	....	....	....	....	Quadruplet symmetrical
50.65	2	1	1	....	0	....	....	?	....	
50.30	..	1	1	....	0	....	....	0	....	
49.78	1—	1	1—	....	0	....	....	0	....	
49.65	3	.., 1	3	....	....	1.82	....	0	....	
49.26	2	..	..	....	....	....	....	....	....	
49.12	1	.., 1	..	....	....	1.27	....	....	....	
48.45	5	2, 4	10	1.50	....	.90	....	0	....	

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	*s*-	*p*-	*s*-			*p*-			
3747.73	10	..	..	....	....	....	....	....	....	Quadruplet symmetrical
46.64	2	..	..	....	....	....	....	....	....	Quadruplet symmetrical
46.15	12	15	30	....	....	+ .94	....	o	....	Triplet symmetrical
45.84	5	.., 2	5	....	....	1.22	....	o	....	No-f and *p*- have a *b* companion inten.=1—
45.38	2	..	1—	....	....	....	....	o	....	
45.11	1	2	1—	....	o	....	....	o	....	
44.89	4	2, 5	10	—1.76	....	.93	....	o	....	On *s*- plate exposed between comps., and *sr* is *o* of 5.11
44.05	1	2	2	....	o	....	....	o	....	No-f and *p*- *dr*
43.71	3	2	6	....	±1.12	....	....	o	....	
43.15	6	3	8	....	1.38	....	....	o	....	
42.45	1	1	2	....	o	....	....	o	....	
41.40	25	..	..	....	....	....	....	....	....	Quadruplet symmetrical
41.02	5	.., 4	8	....	....	.91	....	o	....	*sr* in shadow of 1.40
40.60	1	.., 1	1	....	....	....	....	o	....	
39.95	1—	1	1	....	o	....	....	o	....	
39.02	10	8, 5	15	....	1.04	....	....	o	....	*s*- is probably unsymmetrical, but no-f is not sharp enough on the edges to fix accurately the null position
38.62	1—	..	1—	....	....	....	....	o	....	
37.68	4	2	6	....	1.56	....	....	o	....	*sb o*
37.37	3	2	4	....	1.11	....	....	o	....	*s o*
37.15	2	1+	3	....	1.13	....	....	o	....	*sr o*
35.70	1	..	3	....	....	....	....	o	....	
35.05	4	2	6	....	1.56	....	....	o	....	*sb o*
34.77	4	3	6	....	.87	....	....	o	....	*sr o*

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3733.85	2	1, 1	2	....	....	....	....	o	....	s- broad diff. Probably sym.
33.51	1	..	1	....	....	....	....	o	....	
32.76	2	1, 1	1	....	....	....	....	o	....	Triplet symmetrical
32.47	1	1, 3	1—	....	....	....	....	o	....	Triplet symmetrical; *sb o*
32.38	1	3	1+	....	o	....	....	o	....	
31.60	3	..	..	....	....	....	....	....	....	Quadruplet symmetrical
31.03	1—	1	1	....	o	....	....	o	....	
30.92	8	..	..	....	....	....	....	....	....	Quadruplet symmetrical
30.61	6	.., 2	5	....	....	+ .72	....	o	....	*sr* lost in shadow of 0.92
30.13	1+	..	..	....	....	....	....	....	....	
30.00	1	..	..	....	....	....	....	....	....	
28.05	6	..	..	....	....	....	....	....	....	Quadruplet symmetrical
27.76	2	..	1+	....	....	....	....	o	....	*s- o* 8.05 and 7.47
27.47	3	2	..	....	o ?	....	....	....	....	
27.35	3	..	3	....	....	....	....	o	....	Triplet symmetrical; *s-* too weak
26.89	10	8, 7	15	....	±1.37	....	....	o	....	Triplet symmetrical
26.32	1—	..	1—	....	....	....	....	o	....	
26.02	1—	1—	1—	....	o	....	....	o	....	
25.55	3	2	4	....	o	....	....	o	....	
24.93	4	3, 5	10	....	1.83	....	....	o	....	*sb* probably *o* by 4.70
24.70	1+	1	1	....	....	....	....	....	+ .34	One *sr* comp. between *sr* and *sb* of 4.93. Prob. one *sr o sb* of 4.93. There are one or two diff. *sb* comps. *p-* is weak and possibly a *pr* component
23.85	3	2, 5	6	—1.50	....	1.17	....	o	....	
23.46	2	5	3	....	o	....	....	o	....	
22.35	12	10	20	....	1.40	....	....	o	....	
22.05	15	..	..	....	....	....	....	....	....	9 components unsymmetrical

TABLE XIX—CONTINUED

λ	Intensities			Δλ/λ²						Remarks
	No-f	s-	p-	s-			p-			
3721.76	1—	..	..	....	....	....	....	....	....	
21.64	1	..	..	....	....	....	....	....	....	
21.55	2	.., 1	2	....	....	....	....	....	....	
20.95	2	1+	3	....	....	....	....	o	....	
20.52	15	..	..	....	o	....	....	o	....	
20.18	15	15, 12	25	....	±1.57	....	....	....	....	Quadruplet symmetrical
19.90	1—	.., 1	1	....	....	....	....	o	....	p- broad. Looks 2 or 3 comps.
19.63	10	.., 5	15	....	1.22	....	....	o	....	
19.27	1	..	1	....	....	....	....	o	....	sr o
18.85	1	1, 1	2	....	....	....	— .50	....	....	
18.36	3	2, 2	6	....	1.84	....	....	o	....	
18.02	5	3	8	....	1.24	....	....	o	....	sb o
16.98	1—	..	1	....	....	....	....	....	....	sr o. Quadruplet symmetrical
16.72	2	..	2	....	....	....	....	o	....	
16.42	1—	..	1	....	....	....	....	o	....	
16.29	1—	..	..	....	....	....	....	o	....	
16.01	1—	..	1	....	....	....	....	....	....	
15.82	1+	..	..	....	....	....	....	o	....	
14.53	1	..	..	....	....	....	....	....	....	
12.80	5	2	5, 3	....	....	....	....	....	....	
12.04	1	..	3	....	....	....	....	....	....	Quadruplet unsymmetrical.
11.81	4	..	3, 3	....	....	....	....	o	....	
11.50	10	6, 4	20	....	1.56	....	....	± .74	....	
09.82	5	1, 3	1, 5, ?	....	....	....	....	o	....	p- broad, possibly triplet
08.90	2	3, 2	6	....	1.16	....	....	...	....	Unsym. 5 comps.
07.60	3	..	..	....	....	....	....	o	....	
07.16	3	1	2	....	o	....	....	....	....	Quadruplet symmetrical
06.15	..	2, 1	4	— .48	....	+ .95	....	o	...	

TABLE XIX—CONCLUDED

λ	INTENSITIES			$\Delta\lambda/\lambda^2$		REMARKS
	No-f	*s*-	*p*-	*s*-	*p*-	
3698.47	..	..	..	....	....	Quadruplet symmetrical
98.30	5	..	..	....	....	Quadruplet symmetrical
97.21	..	3, 2	2, 1	....	....	Quad. *p* .75, prob. unsym., *s* diff.
90.27	3	.., 1	2, 1	....	.... + .64	Quad. 0.67, also quad. unsym.
78.16	4	..	..	....	....	Quadruplet unsymmetrical
78.00	1	..	..	....	....	Quadruplet unsymmetrical
77.90	1	2	1	.... 0	.... 0	
56.31	4	2, 1	6	− .55 .... +1.13	.... 0	

of the triplet the *s*- component is supposed to be half the intensity of the *p*- component. Observation shows cases where the intensities are the reverse. When one considers an unseparated line, the simplest assumption would be that the field would change the *p*- and *s*- components relatively the same, and that the intensity of the vibrations parallel and perpendicular to the lines of force would be the same. However, in comparing the *p*- and *s*- components with the no-field line-intensities and with each other, the ratio of their intensities was found to vary in the same way as observed in the triplets. From a comparison of many lines one might infer that the *p*- exposures are at least 25 per cent. stronger than the *s*- exposures. But here one may assume any value less than twofold, for the relative exposure of the *p*- and *s*- plates, and then will find only a small number of the lines to have equal intensity for both *s*- and *p*- exposures. The inference seemed to be that the lines were not vibrating with equal intensity parallel and perpendicular to the lines of force. I soon found there was a tendency for some of these lines to group themselves into pairs, i. e., for one line there was a greater luminosity perpendicular to the lines of force than parallel thereto, and for an adjacent line or close companion the phenomenon was reversed. This reminds one of the close companionship of many of the triplets. There are cases where several of these lines may be associated in close groups. Some of these groups have *s* and *p* nearly equal. Other groups will have *p* stronger than *s* or vice versa. The behavior of these lines led to placing them in a separate table (Table XIX), and to recording the intensities for the no-field lines (designated "no f") as well as the intensities of the *p*- and *s*- components. Special citations from this table would be scarcely necessary unless one could collect them into definite, well-defined, and related groups. A further characteristic is that this group of lines begins very suddenly at its red end, near the beginning of the carbon band. The blue end of the list is nearly reached at 3700, but there seem to be a few scattering lines belonging to the class as far as 3656. There are very few symmetrically separated lines toward the red end of the group, but before reaching the end of the group the symmetrical lines predominate.

There were some of these lines of zero separation which did not

seem to have exactly the same position upon the no-field *s*- and *p*-plates. The lines upon the no-field plates were, in general, exceptionally sharp. But these lines were always broadened. Take, for instance, lines λ 3864.04 and 3751.22. When the corresponding *p*- and *s*- components are compared with each other, one sees an appreciable difference in position. When they are compared with the corresponding no-field lines, the *s*- components fall upon one side and the *p*- components upon the other side of these broad lines. Two adjacent lines, λ 3870.30 and 3870.13, have the *s*- components of the former displaced toward the red and of the latter displaced toward the blue. The no-field lines are again broad in both cases, and the *s*- and *p*- components sharp. Also, these *s*- components do not fall outside of the no-field line. Some other illustrations might be taken from the table. The error naturally increases here owing to the presence of the carbon-band lines and one should not attach much importance to the recorded values of the lateral displacements. But that there are displacements of some of the *s*- and *p*- components without separation as well as a variation in the ratio of their respective intensities from line to line, seems probable. This same broadness or diffuseness upon one side occurs for a few no-field lines which are found to have one of the corresponding *s*- components broader than the other. This action suggests that one has here a pair of close double lines differing but slightly in separation.

Table XX gives a few (38) scattering unseparated lines. There seem to be some easily recognized pairs and groups here. In the table, the pairs (6) are shown in small brackets, and the groups (3) in large brackets. The lines not included in the brackets are more scattered. For the shorter wave-lengths there is increasing probability of small separations escaping one's notice.

General remarks.—It is among the lines which have several components that duplications are most easily recognized. It is also easy to recognize their repetition from substance to substance. But this might be misleading. For if the magnitudes of the separations for a particular number of components change with increased number of lines, they ultimately differ by only small amounts; then one certainly would have separations found in other substances, and a type therefore could have no particular meaning. This is too well known

among triplets to need comment. It is also true in thorium quadruplets. There are, for instance, in this substance a number of lines whose quadruplet separations are reasonably similar to separa-

TABLE XX

	Intensities		Remarks
	s-	p-	
4673.89	2	3	
4436.72	10	6	Adjacent to 6.40 and 6.20
4412.98	25	50	
4311.90	1+	3	
4184.95	5	7	
83.76	5	5	
80.99	5	4	
76.55	4	3	Possibly has an external pair of p-
75.00	1	1	
55.59	1	2	Preceded by two unsymmetrical triplets
55.46	4	5	4.94 is a weak s- doublet
52.45	2	3	
46.13	3	3	
3903.23	6	6	
3597.59	2	3	
90.42	4	3	
90.08	2	2	
89.22	5	6	
88.50	8	2	s o by 8.35
79.62	10	2	s o by 9.45
70.03	3	4	
69.82	3	3	
3545.59	5	6	
45.19	3	4	
44.25	2	3	Probably $s=0$
3498.77	2	5	
73.59	2	4	
24.09	4	8	
3359.87	1	1	
19.13	1+	3	
10.75	1	1	
3270.97	2	2	
57.27	3	5	
40.62	3	3	
35.00	1	1+	
22.00	1+	2	
3190.83	1+	2	
46.15	4	6	

tions which I found in yttrium and zirconium. With such a list of quadruplets and such diversity of separation as found in thorium, it is rather surprising, however, that no quadruplet was found which approached reasonably near to the magnitude of the separation in the quadruplet principal series.

With the lines having five or more components in thorium there are few duplications, and as the number of components increases, the number of representatives of the different types correspondingly decreases. So that there is practically no chance to apply Preston's law in these lists.

As found by myself and others, and in particular by Runge, the successive separations in these several components-lines are for each particular line multiples of small values called "intervals," which Runge[1] first showed were multiples of aliquot parts of a normal separation. In thorium, these small intervals are not as near to aliquot parts of the normal "a" as one should desire for accurate confirmation of such a relationship. But the multiple relationship is frequently very easily recognized.

Besides the small interval there was often a larger interval between the successive s- or p- components, so that these respective s- and p- components were equally spaced. One set of components was slightly displaced as to the other in position. The smaller interval then appeared as a difference in position between a p- and s- component, and the larger interval was a multiple of this difference. Both these types of intervals appear therefore as aliquot parts or multiple aliquot parts of the "normal" separation. Ritz (*Annalen der Physik*, **25**, 660, 1908), in a theoretical discussion of linked electrons, obtained for the p- components

$$(1).\quad \nu_0 = \nu + m\omega;$$

and for the s- components

$$(2).\quad \nu = \nu_0 + \omega' + n\omega,$$

where ν is the separation and m and n are integers. ω and ω' are again intervals and are related $a\omega' = b\omega$, where a and b are integers. When $a = 3b$ the larger interval is three times the smaller, but if $\omega' = (\frac{3}{4})\omega$ the smaller interval in my measurements would appear as $(\frac{1}{4})\omega$.

The Ritz formula has some advantages. He has recently applied it to some of my readings[2] wherein I had recorded no multiples of small intervals. For example, in Table II, λ 4086.71, a common

[1] *Loc. cit.*

[2] An abbreviated discussion of this paper. Moore, *Physikalische Zeitschrift*, **10**, 297, 1909; Ritz, *ibid.*, **10**, 307, 1909.

distance of 0.872. ± .006 occurs nine times. The first *s*- component (which could not be observed accurately) is one-fifth of this magnitude. But before all readings could appear as multiple values it would be necessary to again halve this smaller value. This I had observed but declined to record for the simple reason of its smallness. If one regards 0.872 as $(\frac{3}{4})a$ this value would be one-tenth of $(\frac{3}{4})a$, which certainly could not be regarded as a rational part of the normal "*a*." This is one of the lines which Ritz brings under his formulae, where $\omega/\omega' = \frac{5}{2}$, and $\omega' = \frac{3a}{20}$; here m is even and n odd, but there can be no $n = 1$.

The most important feature of these intervals in the Ritz formulae and Runge's normal "*a*" is their definite relationship to the electron or e/m. Now, as a further example, the larger interval 0.872, above, differs from $\frac{3}{4}$ the normal "*a*" by six times the probable error in, its determination. The same relative deviation exists in ω and ω'.

Concerning these, Ritz remarks that the frequent multiple relationship of the lines of several components confirms one part of Runge's law (and he might have added of his own law), but that the deviation from the "normal" may be disregarded in view of the uncertainty in the determination of the value of e/m. He might also have added that there is an uncertainty in the magnetic field-strength used. But neither objection would be valid, for the comparisons are purely relative. The same assumptions as to field and the value of the "normal" are made as in my study of zirconium and yttrium, and the same as Runge had made in his determinations. Then if the value of e/m should be found to agree with these measurements in thorium it must be wrong in the other substances.

CONCLUSIONS

1. Lines which have six or more components in thorium are relatively very few. The separations of a great many of these are multiples of small values. But these small values are not closely related to aliquot parts of a "normal" separation.

2. There are numerous lines unsymmetrical both in separation and in intensity. The stronger component is always least displaced.

3. There are a few lines with an unequal number of components upon the two sides of the zero position.

4. There are a great many lines unsymmetrical in intensity which fail to show any dissymmetry in position.

5. The components are often unsymmetrical in width, i. e., one component is sharp and its opposite companion is broad. Some of the latter look as if they might separate with stronger field and give lines of the type in conclusion 3.

6. There are numerous lines unseparated in the magnetic field, but very peculiarly affected thereby. Some of them vibrate more strongly perpendicular to the lines of force than parallel thereto, and others vice versa. Some of these are possibly related in pairs. Others may belong in groups.

7. Numerous triplets have one or more close companions of like separation, which suggest pairs and groups of closely related lines.

8. There is often a multiple relationship in the magnitude of the separations of unsymmetrical components. This would be merely a coincidence, if the dissymmetry is independent of the field-strength or proportional to the square of the same.

9. The types of separations for lines which have several components are not repetitions of types which I had found in other substances. Reasons are given for excluding triplets and quadruplets from such a comparison.

10. *General statement upon unsymmetrical types.*—We have, then, the following irregularities in the "Zeeman effect": first, a displacement as noted by Purvis; second, the "Voigt effect" developed from the dispersion equations, noted by H. Nagaoka and S. Amino; third, a variation in displacement proportional to the square of the field-strength, first observed by Gmelin; fourth, a displacement proportional to the field-strength, observed by the author (some of these are different multiples of small values); fifth, an irregularity arising from the splitting of one of the symmetrical components, also observed by the author.

University of Nebraska
Brace Laboratory
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PHOTOGRAPHY OF THE "FLASH" SPECTRUM WITHOUT AN ECLIPSE[1]

By GEORGE E. HALE and WALTER S. ADAMS

Our knowledge of the spectrum of the chromosphere is derived mainly from Young's visual observations and from photographs of the "flash," made during total eclipses of the sun. As most of the bright lines have their origin in a thin stratum close to the photosphere, they are visible only during very short intervals before and after totality. Hence it is impossible, because of insufficient exposure time, to photograph the rich spectrum of this limited region with slit spectrographs of the highest dispersion. For this reason slitless spectrographs, or prismatic cameras, of moderate dispersion are usually employed. These record a great number of lines, but the absence of a slit prevents their wave-lengths from being measured with such precision as is attainable in other fields of solar research. It is impossible, without such precision, to solve various problems relating to the origin and nature of the chromospheric spectrum. For this and other reasons it is important to find a method of photographing the entire "flash" spectrum with high dispersion in full sunlight.

The first attempts in this direction were made by one of us at the Kenwood Observatory in April 1891.[2] The H and K lines, five of the ultraviolet hydrogen lines, and the helium line at λ 3888.73 were photographed with a Rowland grating used in a spectrograph of $42\frac{1}{2}$ inches (1.08 m) focal length. In July 1892 the number of bright lines photographed with the 12-inch visual telescope was increased to 19. After the substitution of a 12-inch (30 cm) photographic objective for the visual one, 28 bright lines were photographed and subse-

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 41.

[2] Hale, *Sidereal Messenger*, **10**, 257, June 1891; *American Journal of Science*, **42**, 160, August 1891; *Astronomy and Astrophysics*, **11**, 50, 602, 821, January, August, November 1892; *Comptes Rendus*, **115**, 106, July 11, 1892.

quently 74 (in a metallic prominence). About the same time many of these bright lines were also photographed by Deslandres.[1]

As the Kenwood observations were made with a 2-inch (51 mm) focal image of the sun, there was reason to hope that many more lines could be seen if a larger solar image were employed. This expectation was fulfilled when the Yerkes 40-inch (1.02 m) telescope was completed. In September 1897 the spectrum of the chromosphere was observed with the Kenwood spectrograph, attached to the Yerkes telescope. A great number of bright lines were visible in the red, yellow, and green, on any day when the seeing was good.[2] These evidently belonged to the normal spectrum of the chromosphere, as they were found at all points on the limb, and not merely in eruptive regions. The advantages offered by the large solar image were clearly shown when the numerous fine lines of the green carbon fluting were found to be reversed at the sun's limb.[3] It was decided to undertake a photographic study of the entire chromosphere spectrum, but the focal length of the Kenwood spectrograph proved to be too short for satisfactory results. The continuation of the investigation was therefore postponed until a suitable spectrograph should become available.

We have already described the advantages offered by the tower telescope and 30-foot (9.1 m) spectrograph on Mount Wilson in other fields of solar research.[4] The solar image given by this telescope is 6.7 inches (170 mm) in diameter. This is slightly less than the diameter of the image given by the Yerkes telescope. In the present case, however, the focal length of the spectrograph is 30 feet instead of 42½ inches. Although the best grating yet available is the one

[1] Deslandres, *Comptes Rendus*, **113**, 307, August 17, 1891; **114**, 276, February 8, 1892; **114**, 578, March 14, 1892.

[2] Hale, *Astrophysical Journal*, **6**, 319, 1897; **6**, 412, 1897.

[3] Hale, "On the Presence of Carbon in the Chromosphere," *Astrophysical Journal*, **6**, 413, 1897.

[4] Hale, "The Tower Telescope of the Mount Wilson Solar Observatory," *Contributions from the Mount Wilson Solar Observatory*, No. 23; *Astrophysical Journal*, **27**, 204, 1908; Hale, "On the Probable Existence of a Magnetic Field in Sun-Spots," *Contributions from the Mount Wilson Solar Observatory*, No. 30; *Astrophysical Journal*, **28**, 315, 1908; Adams, "Spectroscopic Investigations of the Rotation of the Sun during the Year 1908," *Contributions from the Mount Wilson Solar Observatory*, No. 33; *Astrophysical Journal*, **29**, 110, 1909.

used for the Kenwood and Yerkes observations (568 lines per mm, ruled surface 49 mm×82 mm,) the increased focal length of the spectrograph is highly advantageous in separating close lines on the photographs, which can be measured with great precision. Most of the photographs have been taken in the second order, where 1 mm = 0.9 Ångström.

In making the exposure, the essential point is to keep the solar image exactly tangential to the slit. If the image of the photosphere falls on the slit, the brilliant spectrum blots out the comparatively faint lines of the chromosphere. Conversely, if the slit is set a very short distance from the limb, all of the lines given by the vapors at the base of the chromosphere disappear. As it is difficult to move the solar image with sufficient delicacy by the electric slow motion of the coelostat, the following simple device is employed.

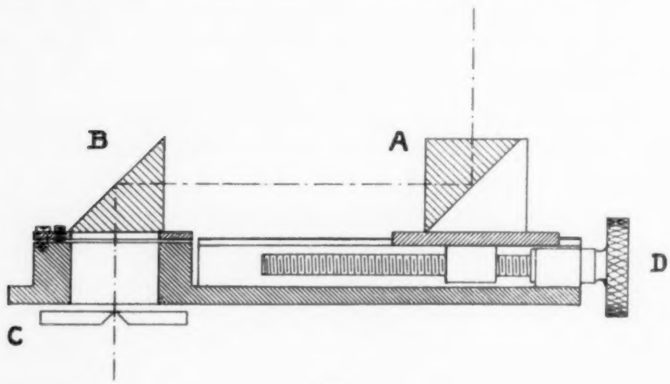
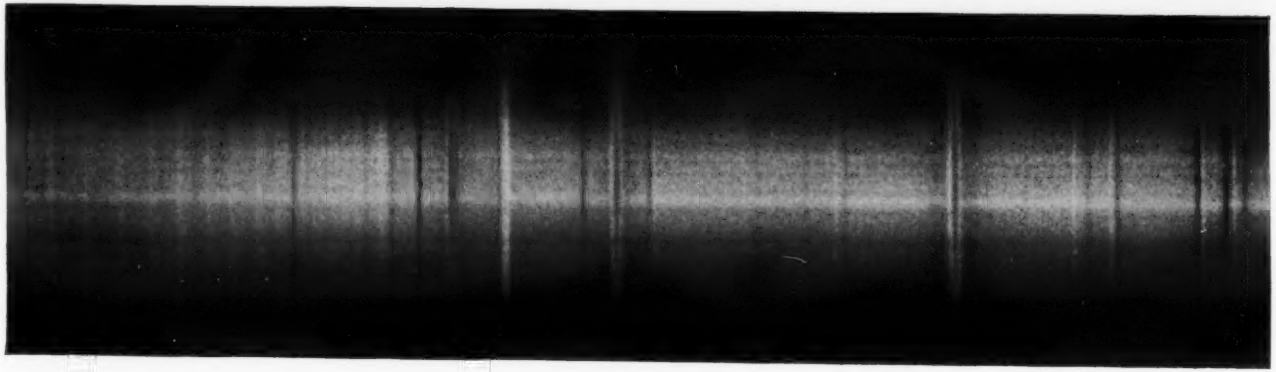


FIG. 1

A right-angle prism *A*, Fig. 1, reflects light from the chromosphere to a second prism *B*, mounted immediately over the slit. The solar image is centered on the slit, and the distance *AB* is equal to the radius. The prism *A* can be moved toward or away from *B* by a screw, which is controlled by the observer throughout the exposure. Watching through an eyepiece a portion of the spectrum adjoining the region to be photographed, he keeps the prism *A* at the point where the bright lines are best seen. If the driving clock is well rated, the change in focus of the solar image produced by the displacement of *A* during the exposure is too slight to be appreciable.

PLATE V



Green Carbon Fluting in the Chromospheric Spectrum
Scale: 1 Ångström = 4 mm

As the 12-inch object-glass of the tower telescope is corrected for the visual region, it is not well adapted for work in the blue and violet, where the color-curve is very steep. In spite of this fact, the bright lines given in the first column of Table I are shown in our photographs of the region λ 4492–λ 4584. A brace joining two lines indicates that they are the bright components of a broad line with a dark center (reversal). The second column gives the intensities of the chromospheric lines. In the third, fourth, and fifth columns are the wave-lengths, origins, and intensities of the corresponding solar lines in Rowland's table. The initials E., F., J., and L., following a line, indicate that it is given in Evershed's, Frost's, Jewell's, or Lockyer's tables of lines in the "flash" spectrum. On account of the uncertainty of some of the eclipse wave-length determinations, it is difficult to make sure of some of these identifications. In some cases, lines which appear double or triple on our negatives are blended into single lines on the eclipse plates. Additional lines in this region which do not appear on our photographs are given in the various tables as follows: Evershed, 7; Frost, 7; Jewell, 6; Lockyer, 11. The two values in the first column in parentheses are the Rowland wave-lengths of solar lines coinciding with "flash" lines which were not directly measured.

In the green, where the visual object-glass performs to much better advantage, the bright lines given in Table II have been photographed between λ 5111 and λ 5198.

All of the bright lines of the green carbon fluting observed visually with the Yerkes telescope are included in Table II. Some of these lines are shown in Plate V, which also covers the *b* region. In eclipse work less attention has been paid to the green than to the more refrangible part of the spectrum. Nevertheless, Jewell gives 4 and Lockyer 10 lines between λ 5111 and λ 5198, which have not been photographed by us.[1] As they failed to get most of our lines in Table II, including several of intensity 2 and 3, and as most of our lines in the blue are enhanced lines, it seems possible that our observa-

[1] Professor Campbell permits us to add that at the eclipse of 1900 he photographed 64 bright lines between λ 4492 and λ 4584 and 27 bright lines between λ 5111 and λ 5198. The latter region is underexposed on his plates, as it is near the extreme end of the recorded spectrum.

TABLE I

"Flash" Lines		Solar Lines (Rowland)			Observed during Eclipse by	Remarks
λ	Int.	λ	Substance	Int.		
4491.455 } 4491.711 }	1 } 1 }	4491.570	*Fe*	2	E. F. J. L.	Enhanced *Fe*
4498.004	1					
4499.656	1	4499.666	—	000	J.(?)	
4501.322 } 4501.558 }	3 } 2 }	4501.445	*Ti*	5	E. F. J. L.	Enhanced *Ti*
4507.141	0	4507.139	—	0000	J.(?)	
4508.463	3	4508.455	*Fe*	4	E. F. J. L.	Enhanced *Fe*
4515.232 }	1 }	4515.342 }	—	0		Enhanced *Fe* blended with another line
4515.468 }	1 }	4515.508 }	*Fe*	3	E. F. J. L.	
4519.774	2	4519.806	—	00		
4520.288 } 4520.538 }	1 } 1 }	4520.397	*Fe*	3	E. F. J. L.	Enhanced *Fe*
4521.295	0	4521.304	*Cr*	0		
4522.532	4	4522.539	—	00	E. F. J. L.	Enhanced *Fe* λ 4522.802 is also reversed
4523.234	3	4523.250	—	0		
4524.070	0	4524.090	—	00	L.	
(4531.123)		4531.123	*Fe ? Co*	2	J. L.	Probably doubly reversed
4534.002 } 4534.252 }	2 } 2 }	4534.139	*Ti-Co*	6	E. F. J. L.	Enhanced *Ti*
4535.605	1	4535.615	—	000	L.	
4535.879			*Cr*	1		Probably reversed
4538.130	0	4538.138	—	00N	J.(?)	
4539.249	2	4539.263	—	00		
4539.908	2	4539.946	*Cr*	0N	E. L.	
4541.678	1	4541.690	*Cr*	2	E. J.(?) L.	
4545.585	1	4545.568	—	00		
4549.544 } 4549.693 }	2 } 1 }	4549.642	*Fe*	2	} J. L.	Enhanced *Fe*
(4549.808)		4549.808	*Ti-Co*	6d ?	E. F. }	Enhanced *Ti* reversed but components lacking
4552.836	0	4552.824	—	000	J.	
4553.212	0	4553.219	—	00		
4554.051 } 4554.349 }	2 } 2 }	4554.211	*Ba*	8	E. F. J. L.	
4556.084	4	4556.063	*Fe*	3	E. F. J. L.	Enhanced *Fe*
4558.664	3	4558.640	—	00	E. F. L.	Perhaps violet component of enhanced *Cr* λ 4558.827
4560.426	2	4560.457	—	00	E.	
4560.890	1	4560.892	—	00	J. L.(?)	
4562.540	4	4562.541	—	0	E.	
4563.816 } 4564.051 }	2 } 2 }	4563.939	*Ti*	4	E. F. J. L.	Enhanced *Ti*
4566.002	2	4566.031	—	000	L.	

TABLE I—*Continued*

"Flash" Lines		Solar Lines (Rowland)			Observed during Eclipse by	Remarks
λ	Int.	λ	Substance	Int.		
4571.986	3	4572.156	*Ti*	6	E. F. J. L.	Enhanced *Ti*
4572.299	1					
4572.449	3	4572.366	—	000		
4576.526	2	4576.512	*Fe*	2	E. J. L.	Enhanced *Fe*
4577.866	2	4577.868	—	00		
4583.001	1	4583.011	—	1		
4583.935	0	4584.018	*Fe*	4	E. F. J. L.	Enhanced *Fe*
4584.110	1					

Additional Lines Given by

Evershed	Frost	Jewell	Lockyer
4494.3	4494.5	4495.1	4493.8
4496.9	4496.3	4513.6	4494.3
4518.3	4511.7	4525.9	4495.2
4529.0	4518.0	4544.8	4496.8
4536.3	4525.0	4569.0	4505.5
4545.0	4528.6	4581.1	4505.5
4580.1	4580.1		4512.3
			4518.8
			4544.8
			4567.4
			4580.0

tions relate to a level somewhat higher than that best photographed at eclipses. In any event, there is reason to hope that the number of bright lines obtainable in full sunlight will be considerably increased when the new tower telescope of 150 feet (45.7 m) focal length, now being erected on Mount Wilson, is completed.

The wave-lengths of all lines photographed on Mount Wilson in the spectrum of the chromosphere will soon be published. The values given here are provisional, but of sufficient accuracy to demonstrate that the chromospheric lines coincide very closely in position with the Fraunhofer lines, as measured by Rowland. If we omit three lines, which are unsuitable for purposes of comparison because of their uncertain identification or character, 121 lines remain in our list. Comparing their wave-lengths with those of the corresponding lines in Rowland's table, we find the average residual, taken without regard to sign, to be ± 0.013 Å. If we retain the sign, the average

TABLE II

"Flash" Lines		Solar Lines (Rowland)			Observed during Eclipse by	Remarks
λ	Int.	λ	Substance	Int.		
5110.929	0	5110.938	*Cr*	00		
5111.827	0	5111.802	–	000		K and R give *C*
5112.443	3	5112.458	–	000		K and R give *C*
5113.256	0	5113.298	*Cr*	00		
5114.424	1	5114.431	–	000Nd ?		K and R give *C*
5114.739	3					
5116.045	0	5116.045	–	0000		
5116.829	1	5116.849	–	0000		K and R give *C*
5117.019	1	{ 5116.944	–	000		
		5117.071	–	000		
5117.341	0	5117.334	–	0000		K and R give *C*
5118.301	1	{ 5118.241	–	0000		K and R give *C*
		5118.352	–	0000		
5119.323	1	{ 5119.292	–	00		K and R give *C*
		5119.368	–	0000		
5119.546	0	5119.555	–	000		
5120.575	1	5120.592	*Ti*	0		
5120.848	1	{ 5120.802	–	000		
		5120.893	–	0000		
5121.602	1	5121.609	–	0000	L	K and R give *C*
5122.454	0	5122.481	–	0000		K and R give *C*
5123.187	2	5123.178	–	000		K and R give *C*
5123.382	1	5123.390	*Y*	0	L.(?)	
5124.918	0	5124.939	–	0000		K and R give *C*
5126.179	1	5126.167	–	0000		K and R give *C*
5130.763	3	5130.757	–	000	L.	
5131.765	1	5131.771	*C*	0000		
5132.505	1	5132.523	–	000		K and R give *C*
5132.844	1	5132.843	–	00		Probably *C*
5133.637	1	5133.654	–	000		Probably *C*
5134.851	0	5134.849	–	0000		Probably *C*
5135.329	1	5135.355	–	0000		
5135.786	1	{ 5135.752	*C*, –	000		
		5135.880	*C*, –	000		
5136.947	1	5136.969	–	000		
5137.774	1	5137.753	*C*, –	000	L.	
5138.516	0	5138.518	–	0000		K and R give *C*
5138.696	0	5138.690	–	0000		Probably *C*
5141.381	1	5141.386	*C*, –	000		
5143.502	0	5143.511	–	000	L.	
5144.742	0	5144.758	*C*, –	000		
5146.306	3	5146.291	*C*, –	00		
5146.963	1	5146.945	*Co*	000d ?		
5147.927	1	{ 5147.871	*C*, –	000		
		5147.992	*C*, –	000		
5149.267	0	5149.267	*C*, –	000		
5150.810	2	{ 5150.736	–, *C*	000		
		5150.842	*C ?*	0000		
5153.388	1	{ 5153.337	*C*	0000		
		5153.414	*Fe*	1		
5154.543	2	5154.505	*C*	0000		
5155.695	1	5155.694	*C*, –	000		

TABLE II—*Continued*

"Flash" Lines		Solar Lines (Rowland)			Observed during Eclipse by	Remarks
λ	Int.	λ	Substance	Int.		
5156.785	1	5156.728	*C*	0000		
		5156.823	*C*, —	00N		
5157.763	1	5157.783	—, *C*	000		
5157.954	1	5157.915	*C*, —	000		
5158.667	1	5158.701	*C*	000		
5160.080	1					
5160.419	1	5160.419	*C*, —	00N		
5160.553	0	5160.554	—	0000		
5161.214	0	5161.194	*C*, —	000		
5161.335	1	5161.353	*C*, —	000		
5161.861	1	5161.849	*C*	0000		
5162.144	0	5162.153	*C?*	0000		
5162.716	0	5162.690	*C*	0000		
5163.043	0	5163.074	*C*, —	000		
5163.242	0	5163.200	*C*, —	000		
5163.564	0	5163.585	*C*, —	000		
5163.773	0	5163.756	*C*, —	000		
5164.084	0	5164.007	—	0000		
		5164.172	*C*	0000		
5164.508	1	5164.404	*C*, —	000		
		5164.562	—	0000		
5164.918	0	5164.855	*C*	0000		
		5164.950	*C*	0000		
5165.287	2	5165.297	*C*	0000		
5167.370	1	(5167.497	*Mg*	15)	E. J. L.	Violet component. Red component lacking
5169.141	2	5169.220	*Fe*	4	J. L.	Enhanced *Fe*
5169.298	5					
5172.711	3	5172.856	*Mg*	20	E. J. L.	
5173.004	2					
5173.681	0	5173.652	—	000		
5174.067	1	5174.077	—	0000		
5176.947	0	5176.954	*V*	000		
5179.949	1	5179.958	—	000		
5180.746	0	5180.747	—	000		
5181.330	0	5181.334	—	000		
5182.764	0	5182.761	—	0000		
5183.616	4	5183.791	*Mg*	30	E. J. L.	
5183.950	3					
5184.747	0	5184.738	*Fe,Ni,Cr*	1		
5186.284	0	5186.274	—	0000		
5187.640	1	5187.620	—	000		
5188.855	3	5188.863	*Ti*	2	J. L.	Enhanced *Ti*
5191.773	2	5191.768	—	000	J. L.	
5192.147	0	5192.155	*Cr*	00		
5192.801	2	5192.785	—	000		
5196.605	0	5196.613	*Cr*	0		
5197.743	5	5197.743	—	2	J	

ADDITIONAL LINES GIVEN BY

Jewell	Lockyer
5128.8	5115.5
5180.2	5148.2
5192.0	5151.0 }
5194.9	5152.0 }
	5154.2
	5156.0
	5162.4
	5178.0
	5191.5 }
	5192.5 }

systematic deviation comes out +0.002 Å., which is much less than the error of measurement.

According to Julius, the bright lines of the "flash" spectrum are due to the anomalous refraction of white light at the sun's limb. If this were the case, however, we should expect their wave-lengths to differ appreciably from their normal values, being somewhat increased on the usual assumption of a density gradient decreasing outward from the surface of the sun.[1] As the green carbon fluting probably gives no anomalous dispersion, it is of interest to remark that the average residual for the 30 lines of this fluting in Table II is ±0.018 Å., which is greater than the average residual for the entire series of 121 lines, owing probably to the inferior character of the fluting lines for purposes of measurement. There is thus no reason to doubt that the differences in wave-length between the "flash" and the solar lines are due almost wholly to accidental errors of measurement. So far as these provisional results are concerned, accordingly, they are opposed to the hypothesis of Julius, at least to the extent of reducing the effect of anomalous dispersion to a very small amount for the average of a considerable number of lines. Whether individual lines may be more affected will be considered in future papers when a larger amount of material is available for discussion.

MOUNT WILSON SOLAR OBSERVATORY
August 1909

[1] Hartmann, *Astronomische Nachrichten*, **175**, 347, 1907.

ON THE SPECTRA OF SOME OF THE COMPOUNDS OF THE ALKALINE EARTHS

By ALBERT EAGLE

In view of the presence of magnesium hydride in the sun-spot spectrum discovered by A. Fowler,[1] and of calcium hydride subsequently found by C. M. Olmsted,[2] it seemed worth while to look for the presence of the hydrides of barium and strontium.

For this purpose arcs of these metals were run in an exhausted globe of about four liters capacity into which hydrogen had been introduced. The pressure of hydrogen usually worked with was about 40 mm. As it was not possible to obtain either metallic barium or strontium, their chlorides were used on carbon poles. It was doubted at first whether the use of the chlorides would be successful, but work with calcium showed that the hydride bands at λ 6382 and λ 6389 were obtained with the chloride as well as with the metal itself, although they were not so strong as in the latter case, and were very weak compared with the chloride bands. In the case of both barium and strontium spectra have been obtained which are believed to be characteristic of the hydrides of these elements.

The hydride spectra were photographed in the first order of a 10-foot Rowland concave grating. For most of the work in this paper, however, a large one-prism Littrow spectrograph, giving a dispersion of 8.2 t.-m. per mm at D, was employed, as the temporary mounting of the grating made its use inconvenient.

As it was necessary to produce evidence that the new band spectra were due to the hydrides and not to other compounds, I was led further to examine the bands which are given by the oxides and chlorides of these elements in air. These band spectra are most readily obtained from the electric arc by exposing several times as long as is necessary to photograph the arc spectrum, but they are then somewhat disfigured by the very much overexposed arc lines. Better results are obtained

[1] *Monthly Notices*, **57**, 530, 1907.

[2] *Astrophysical Journal*, **27**, 66, 1908.

by keeping the image of the core of the arc off the slit and allowing only that of the surrounding flame to cover it. To facilitate this the flame may be spread out as a fan by bringing a horseshoe magnet near it. This, however, drives the arc itself to the edge of the carbons and renders it unstable, but if an alternating current be employed, the core of the arc will remain central, while the surrounding flame will be spread out as a broad fan on either side. This incidentally shows that the molecules in the flame giving rise to the bands are not electrically neutral, as, if so, the magnet would be without influence. Figs. 1 and 4 of Plate VI were taken in this way with an alternating arc. Save for an occasional erratic wandering of the arc, causing it to come on the slit, the flame bands could, in this way, have been obtained free from the arc lines, while the exposure necessary was many times less than would have been required to photograph ordinary flames.

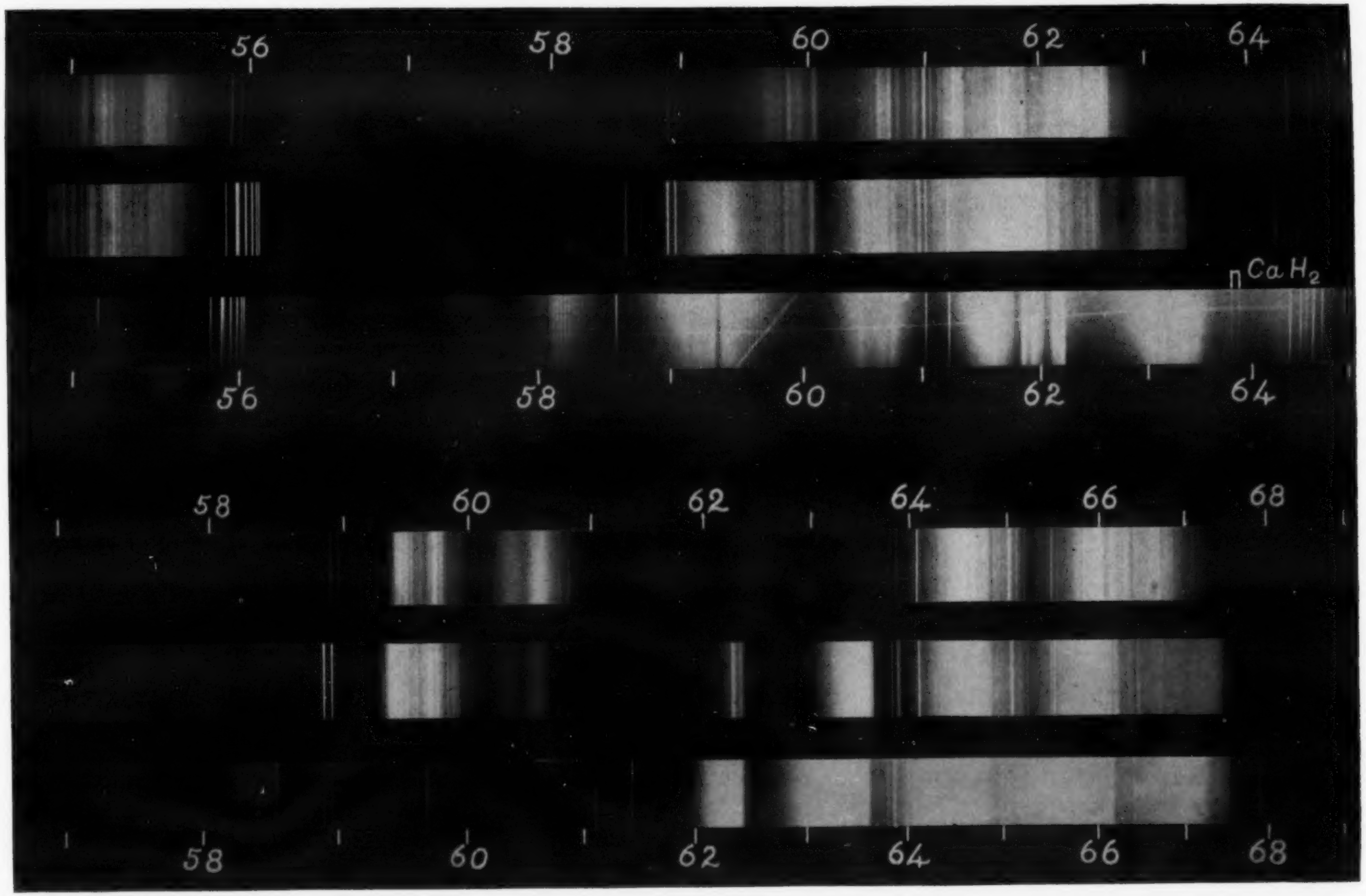
When using direct current, the intensity of the arc lines can be greatly diminished by making the lower pole negative instead of positive, and using as small a current as will maintain the arc. Still further advantage in the latter direction can be obtained by running the arc off high-voltage mains of 200 or 500 volts, in which case a few glow lamps afford a suitable resistance. Figs. 2, 5, Plate VI, and figs. 7, 8, Plate VII, were obtained in this way, the exposures being only of five minutes, whereas Eder and Valenta in photographing the same bands from flames needed exposures of many hours. The time of exposure required for ordinary arc spectra with the instrument employed is from one-half to one minute.

When using barium chloride with the lower pole positive it was noticed that the surrounding green flame giving rise to the chloride bands sprang from the material which had been carried over and deposited on the upper pole and did not reach the lower pole at all, which was filled with the salt. This obviously led to making the lower pole negative.

CALCIUM

Fig. 1, Plate VI, indicates the bands given by calcium oxide in air, while Fig. 2 was obtained from the chloride in air, and shows both the oxide and chloride bands. Fig. 3 is the spectrum of the chloride in hydrogen, showing, besides the chloride bands, the heads of the hydride bands at λ 6382 and λ 6389 which are just visible. The

PLATE VI



(1) CaO in air. (2) $CaCl_2$ in air. (3) $CaCl_2$ in H.
(4) SrO in air. (5) $SrCl_2$ in air. (6) $SrCl_2$ in H.

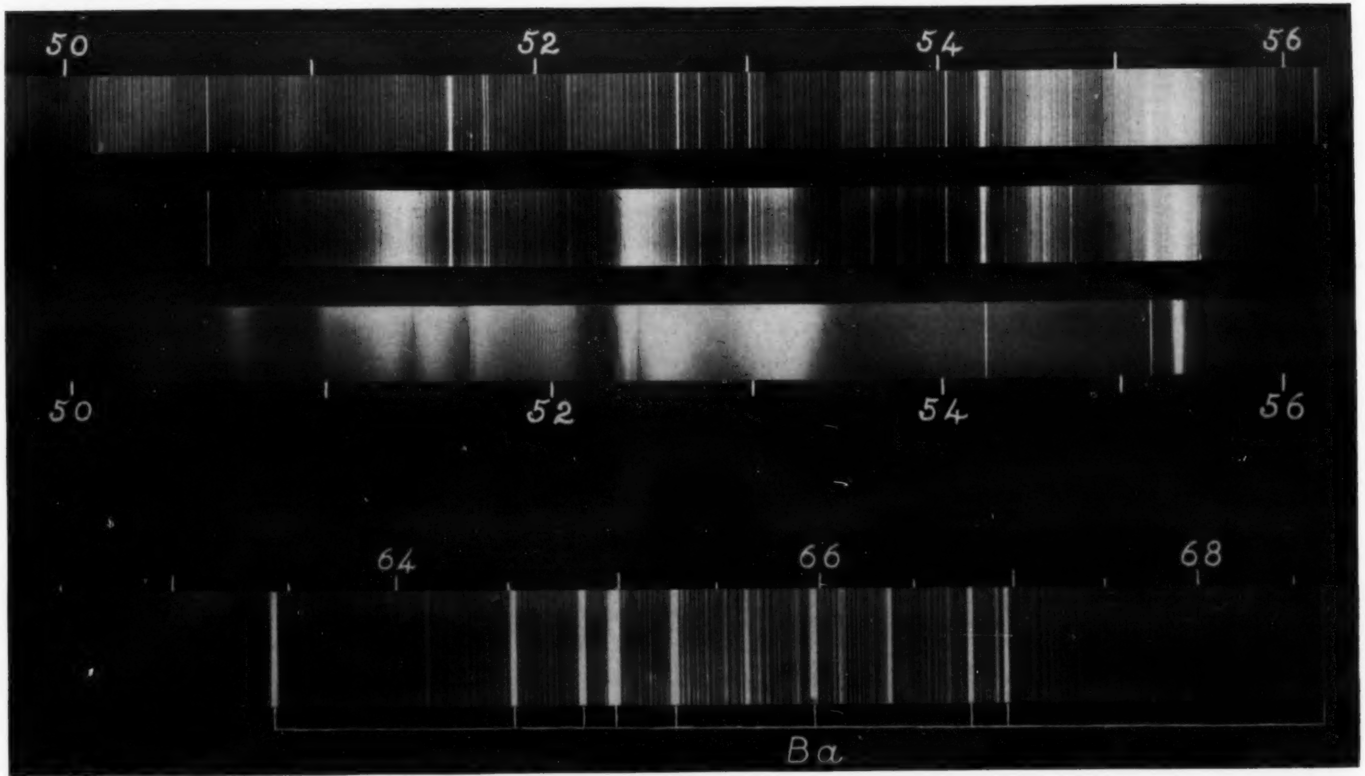
PLATE VII

7

8

9

10



(7) BaO in air. (8) $BaCl_2$ in air. (9) $BaCl_2$ in H.
(10) Barium Hydride Bands from $BaCl_2$ in H.

oxide bands are quite absent, which it is impossible to secure when photographing band spectra of different salts from flames in air. Attention must be drawn to the fact that the heads of the chloride bands at λ 5934, λ 6183, and λ 6202 in Fig. 3 are photographically reversed owing to overexposure.

Tables of the wave-lengths of the heads of the oxide and chloride bands of calcium, and also for those of strontium and barium, have been published by Eder and Valenta,[1] but as these bands cannot be well described by a list of heads, it has been thought useful to reproduce photographs of them which will help to interpret the tables. It may be noted that the chloride bands were also obtained—though not so strongly—when the metal itself was used, but as no trace of these bands could be obtained from the oxide in air, there seems to be no reason to doubt that they are really due to the chloride and not to the metal itself. A chemical test showed that the metal employed was by no means free from chlorine.

BARIUM

Fig. 7, Plate VII, shows the flutings given by barium oxide in air, while Figs. 8 and 9 show those given by the chloride in air and hydrogen respectively.

The origin of the splendid fluted spectrum given by barium oxide in air—of which only a small portion is reproduced—has been regarded as uncertain. From its total dissimilarity to the oxide bands of calcium and strontium it has been thought that it is more likely to be due to the metal itself than to the oxide,[2] while it is supposed that the analogous bands of barium oxide may be in the infra-red, in accordance with the displacement of analogous bands toward greater wave-length with increasing molecular weight.

No trace of this spectrum appeared when the arc was run in hydrogen, but the pressure was low (about 40 mm) and the flutings, if belonging to barium, would probably be due to complex molecules which the low pressure would tend to dissociate. Hence the negative result could not be regarded as establishing anything. An arc with

[1] *Sitzungsberichte des Kais. Akad. der Wissenschaft,* Wien, Bd. CII, Abth. IIA. See, also, Watts, *Index of Spectra*, Appendix F.

[2] Hagenbach and Konen, *Atlas of Emission Spectra*. English edition by A. S. King.

barium chloride (anhydrous) was therefore run in hydrogen at atmospheric pressure, but again the bands failed to appear. It is well known, however, that the presence of hydrogen tends to extinguish the flame lines in the arc spectrum,[1] and since the band spectrum in question is a flame spectrum, it was thought that its suppression might result from a similar cause, if it were due to the metal itself. Hence the arc was tried in nitrogen. For this purpose the globe was exhausted and washed out three or four times with hydrogen. Nitrogen was then introduced by causing air to bubble slowly through five tubes containing a mixture of nearly saturated solutions of caustic potash and pyrogallic acid, and finally through a tube containing concentrated sulphuric acid. In this way oxygen, carbon dioxide, and water-vapor were removed from the air. No trace whatever could be seen of the flutings in question though they came out at once when air was admitted. Hence there seems little doubt that the presence of oxygen is necessary for their production and I therefore ascribe them to an oxide.

It is difficult, however, to think that these flutings can be analogous to the band spectra of calcium and strontium oxides, and hence it is provisionally suggested that they may belong to the peroxide of barium, BaO_2. In this connection attention may be drawn to the similarity in type between these flutings and those of titanium oxide, TiO_2.[2]

THE BARIUM HYDRIDE BANDS

In the spectrum of barium chloride in hydrogen, besides the chloride bands, some fainter ones of an entirely different character appeared in the region λ 6300 to λ 6900; these are shown in Fig. 10. These flutings resemble the magnesium hydride flutings in being degraded toward the violet and everywhere clearly resolved into distinct lines. Definite heads occur at wave-lengths $\lambda\lambda$ 6632.8, 6689.0, 6806.9, 6808.8, 6825.6, 6827.1, 6848.7, 6850.1, and 6923.2 on Rowland's scale. The head at λ 6632.8 is the strongest, while the one at λ 6923.2 is very faint. Other series of lines which do not

[1] Crew, *Astrophysical Journal*, **12**, 167, 1900. See, also, Fowler, "On the Spectrum of Scandium and Its Relation to Solar Spectra," *Roy. Soc. Phil. Trans.* A, **209**, 47.

[2] A. Fowler, "The Fluted Spectrum of Titanium Oxide," *Proc. Roy. Soc.* A, **79**, 509, 1907.

start from a definite point as head enter at about λ 6611 and at other places not easy to define, and fade off toward the violet.

These bands were subsequently photographed under a much higher resolving power with the 10-foot grating, and compared with Professor Hale's map of the sun-spot spectrum. The spot spectrum is greatly complicated in this region by the mass of Zeeman triplets into which the Fraunhofer lines are decomposed[1] and also by the presence of the flutings of titanium oxide.[2] Most of the new flutings could not be seen in the spot spectrum at all, but as there appeared to be what looked like two heads of flutings at λ 6848.7 and λ 6850 in the spot, agreeing in position with two of the heads of barium hydride flutings, the case was considered uncertain and held in abeyance till Professor Hale's new map of the spectrum became available.

Hearing of the attempt to establish the presence of barium hydride in sun-spots during his recent visit to England, Professor Hale kindly forwarded advance positives of his new sun-spot map in the red, giving a dispersion of 1.13 mm per t.-m., in the region investigated. From a comparison with this, I am obliged, however, to think that barium hydride is absent from the sun-spot spectrum.

As the spectrum of barium hydride in consequence appears to be of no immediate interest, the brief description given above will suffice.

STRONTIUM

Fig. 4, Plate VI, shows the bands given by strontium oxide in air, while Figs. 5 and 6 show the bands produced by the chloride in air and hydrogen respectively. No bands other than those of the chloride were obtained in the latter case. In view of the possibility that the hydride bands might be covered up by the very strong chloride bands, some anhydrous strontium iodide was prepared. This gave flutings of the same nature as those of magnesium and barium hydrides, which, as they could not be obtained from the iodide in air, are presumed to be the hydride flutings. Like the other hydride flutings they are degraded toward the violet and are clearly resolved into separate lines. Heads of the flutings occur at $\lambda\lambda$ 6974.8, 6990.0, 7009.6, and 7018.2, the first two being rather ill-defined. Com-

[1] Hale, *Astrophysical Journal*, **28**, 315, 1908.

[2] Hale, *ibid.*, **25**, 75, 1907.

ponent lines of the flutings can be traced down to λ 6840. Possibly some more of this spectrum exists but is covered by the chloride and iodide bands.

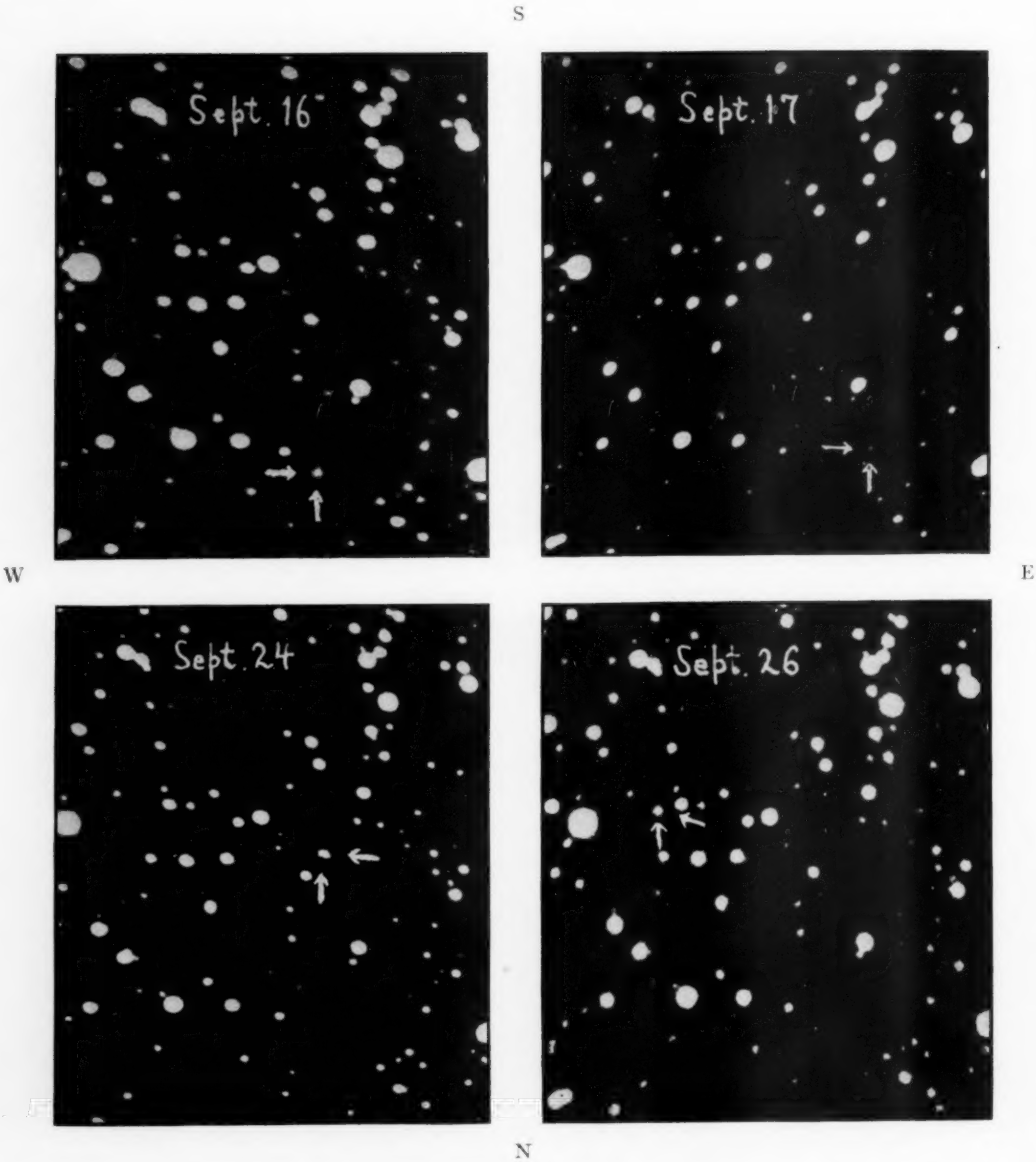
The reason why the hydride flutings were not obtained from the chloride was not because of the presence of the chloride bands, but probably because the chloride does not give them so readily as the iodide.

As in the case of barium hydride, the chief interest in investigating this spectrum was in view of the possibility of its being in sun-spots. A comparison with the spot spectrum fails, however, to show any evidence of its presence.

I am indebted to Professor Fowler for the interest he has taken in the foregoing work and for the facilities which he has given me for carrying it out.

Imperial College of Science and Technology
London
July 1909

PLATE VIII



HALLEY'S COMET AS PHOTOGRAPHED WITH TWO-FOOT REFLECTOR OF YERKES OBSERVATORY
Scale: 1cm = 1′.3

PHOTOGRAPHS OF HALLEY'S COMET

By OLIVER J. LEE

The search for Halley's comet made last winter with the two-foot reflector of the Yerkes Observatory was to be resumed as soon as the field could be reached this autumn. The inference then was that either the comet was not within a degree or two of its computed place or it was fainter than the 17th photographic magnitude,[1] the latter alternative being preferred. In a recent discussion[2] of his plates taken at Taunton, Mass., Mr. Joel H. Metcalf reaches a similar conclusion.

The full aperture of 24 inches was employed for the present photographs, as for the earlier ones. The mirror had been resilvered early this summer by Mr. Parkhurst, which added materially to its light-power. A fresh emulsion of Lumière "Sigma" plates was used, which, when tested with the Scheiner sector sensitometer, which has here been adapted for the daylight comparison of two plates simultaneously, proved to be faster by one stellar magnitude than the "Seed 27" with which it was compared. It was, moreover, almost free from defects in the film which made very difficult the detection of faint objects on the earlier emulsions of this new brand of plates.

Moonlight and cloudy weather prevented satisfactory exposures upon the field until the night of September 15, four days after the comet had been discovered by Wolf at Königstuhl. It was, however, not until another photograph had been made on the next night that the comet was detected, for the reason that its photographic image on the first plate was partly covered up by that of a faint star, the combination appearing on the plate as a close double.

The original negatives have been enlarged 11 times in making the reproductions, the scale of which is about $7''.8$ per mm, or $3'.3$ per inch. The width of each picture is, therefore, $8'$. The position predicted from Cowell and Crommelin's elements thus lies within the width of the picture from its observed place. The arrows on the plate indicate the position of the comet, and also the components

[1] *Popular Astronomy*, **17**, 160, 1909. [2] *Ibid.*, **17**, 440, 1909.

of its direction of motion. It will be seen that the comet's apparent motion was toward the east and south on September 16 and 17, and toward the west and south on September 24 and 26, retrogression having commenced between the two pairs. The faintness of the images on September 17 was due to an unfavorable sky.

The bright star shown at the left edge of the pictures is No. 2122 of the Berlin A. G. Catalogue (mag. 8.7), or *B.D.* $+17°1232$ (mag. 8.8), and is the only catalogue star on the part of the plate reproduced. The original negatives, having a much larger field, show a number of catalogue stars.

The comet's positions, as measured on these four negatives, are as follows:

1909	Central Standard Time of Mid-Exposure	Exposure	App. α	App. δ
Sept. 16.....	$14^h\ 45^m$	180^m	$6^h\ 18^m\ 56^s$	$+17°\ 9'\ 23''$
17.....	14 10	130	6 19 0	17 9 0
24.....	14 27	150	6 18 58	17 6 10
26.....	15 17	60	6 18 44	17 5 20

Mr. Parkhurst has derived the photometric reduction-curves necessary for the brand of plates used, preparatory to his photometric researches on the comet. His measures of the approximate magnitude of the comet are:

September 16	Magnitude 16
17	16
24	$15\frac{1}{2}$
26	$15\frac{1}{2}$

The faintest stars having well-defined images on the negative of September 24 are of magnitude 17; these are readily visible on the engravings of September 24 and 26.

The exposure of $2\frac{1}{2}$ hours on September 24 was made under very good conditions, and a black core runs through the image of the comet. The width of this core, due presumably to the nucleus of the comet, was measured and found to be $3''.5$. When the penumbral parts of the image are included, the width of the trail, which may, perhaps, be taken as a rough estimate of the diameter of the comet, is $8''$.

YERKES OBSERVATORY
October 4, 1909

SEVEN SPECTROSCOPIC BINARIES

By S. A. MITCHELL

Following a plan of co-operation entered into with the director of the Yerkes Observatory the writer spent the summers of 1907 and 1909 at the observatory photographing, measuring, and reducing plates for the determination of motion in the line of sight. Spectrograms were also sent to Columbia University and were measured there. Measures at Columbia were made partly with a Gaertner dividing engine and partly with a Zeiss comparator, and reductions were carried out after the method regularly used with Bruce spectrograms. At Yerkes the measuring machine used was the Gaertner, G1, and the reductions were made in part by Schlesinger's abridged method. Among the stars measured were the following, whose radial velocities are variable:

β Equulei ($\alpha = 21^h\ 18^m$; $\delta = +6°\ 0'$; Mag. = 5.1)

Plate	Date	G. M. T.	Taken by	Center No. Lines	Center Velocity	Viol. Comp. No. Lines	Viol. Comp. Velocity	Red Comp. No. Lines	Red Comp. Velocity	Quality
					km		km		km	
IB 1121	1907 Aug. 5	$17^h\ 7^m$	F	16	− 8.6					e.
1133	Aug. 10	20 14	F	15	− 9.4					g.
1137	Aug. 12	16 51	M	16	−11.2					e.
1145	Aug. 23	20 36	M	19	− 9.8					g.
1154	Sept. 2	16 39	M	12	−11.3	8	−34.6	5	+10.0	g.
1160	Sept. 13	14 55	F	9	− 3.5	3	−29.2	3	+24.8	g.
1169	Sept. 21	15 59	F	11	−10.3					f.
1206	1907 Oct. 18	15 39	F	14	−14.7					e.
1674	1908 Aug. 10	19 39	L	6	−12.3					f. w.
2042	1909 June 4	22 42	L	8	− 2.0					f. w.
2048	June 14	20 48	M	10	− 2.6					g.
2056	June 18	20 34	F	13	−10.8	3	−39.2	3	+14.7	g.
2063	1909 June 25	19 58	M	10	−12.4					f.

Observers: F=Frost; A=Adams; B=Barrett; L=Lee; M=Mitchell. Mr. Sullivan, as usual, assisted in the guiding. Under quality, e=excellent; g=good; f=fair; w=weak; p=poor; v=very.

Plates 1121 and 1133 were measured by Miss Flora E. Harpham, formerly chief computer at Columbia; Plate 1137 is the mean of two measures by Miss Harpham and by Mitchell. The lines on many of the spectrograms seemed very complicated in appearance, but on only three of the plates was it possible to separate the lines

into their components. Under these circumstances what meaning the velocity determined from the center of the line has is hard to tell. However, a period of 22.7 days seems to fit in very satisfactorily with the observations. The spectrum of *β Equulei* is of Vogel's type Ia2, with numerous well-defined lines.

β Trianguli ($\alpha = 2^h\ 4^m$; $\delta = +34°\ 34'$; Mag. = 3.1)

Plate	Date	G. M. T.	Taken by	Center No. Lines	Center Velocity	Viol. Comp. No. Lines	Viol. Comp. Velocity	Red Comp. No. Lines	Red Comp. Velocity	Quality
					km		km		km	
B 694*	1906 Dec. 28	$12^h 10^m$	B	10	+14.7					f.
IB 1179*	1907 Sept. 23	20 31	L	17	− 6.8					g.
1190	Oct. 7	20 30	L	25	+23.3					f.
1196*	Oct. 11	16 48	B	22	+ 1.3					v. g.
1207	Oct. 18	17 06	F	22	− 9.7					g.
1231*	1907 Oct. 22	16 26	F	19	− 7.3					g.
1722	1908 Sept. 7	20 47	L	14	+54.4					f.
1732	Sept. 8	21 13	B	14	+52.5					g.
1739	Sept. 18	18 55	B	18	− 9.0					g.
1773	Oct. 5	16 05	L	10	+ 2.1					f.
1791	Oct. 12	16 58	L	13	+33.5	4	−12.8	6	+51.0	e.
1834	Nov. 8	16 45	F	15	+30.6	3	− 4.2	3	+60.2	g.

* Measured by Miss Harpham.

The spectrum of *β Trianguli* is of Vogel's type Ia2 with numerous well-defined lines. Like *β Equulei*, many of the lines appear complicated, and on two plates it was possible to separate some of the lines. This star will be photographed with a greater dispersion than one prism in order more widely to separate the components. A period of thirty-seven days satisfies the observations.

γ Lyrae ($\alpha = 18^h\ 56^m$; $\delta = +32°\ 34'$; Mag. = 3.3)

Plate	Date	G. M. T.	Taken by	No. of Lines	Velocity*	Quality
					km	
IB 779	1906 June 1	$19^h 22^m$	F	11	− 9.6	v. g.
800	July 13	15 56	B	12	−16.2	f.
808	July 20	18 41	B	8	−21.6	g.
1114	1907 July 26	15 38	B	5	−19.2	p.
1166	Sept. 16	16 28	L	7	−16.9	f.
1223	Oct. 21	16 30	L	7	−28.3	f. w.
2036	1909 May 31	20 54	M	5	−27.4	g.
2047	June 14	19 27	M	9	−15.5	g.
2053	June 18	16 23	M	6	−20.5	g.
2058	June 21	18 44	M	6	−23.4	f.
2061	June 25	16 47	B	7	−28.4	g.

The spectrum of γ Lyrae is of the Ia2 type, with not so many well-defined lines as in *β Equulei* or *β Trianguli*. The lines on many of the plates look suspiciously double, yet it was impossible to separate them into their components. A period of 25.6 days fits in well with the observations.

θ Virginis ($\alpha = 13^h\ 5^m$; $\delta = -5°\ 4'$; Mag. $= 4.6$)

Plate	Date		G. M. T.	Taken by	No. of Lines	Velocity	Quality
						km	
IB 735	1906	Apr. 20	16^h58^m	B	9	+ 3.3	p.
756		May 11	15 27	B	8	+ 5.5	f.
964	1907	Jan. 26	21 23	Fox	14	− 1.4	v. g.
IB 1002		Feb. 22	23 06	B	10	+ 4.3	f.
IIB 121		May 25	14 54	Fox	9	− 0.8	e.
IIB 132		May 28	14 46	B	10	− 1.6	e.
IB 1306		Dec. 16	23 15	Fox	12	+16.3	p.
1325	1908	Jan. 13	23 02	B	17	+ 7.3	g.
2038	1909	June 4	16 19	F	16	− 0.4	g.
2043		June 11	15 19	F	6	− 5.6	f. w.
2052		June 18	15 14	M	16	− 3.9	g.

The spectrum of *θ Virginis* is of the Ia2 type, with many well-defined lines, and with sharp H and K. On only three of the plates were H and K measurable, and as these give velocities widely differing from those of the plate as a whole, they were not included in the values given in the table. The radial velocity from H and K on Plate 964 was +14.6 km per second, that from the whole plate −1.4 km; a measure of K on Plate 1002 gave the velocity +5.2 and on Plate 1325, −6.7. These measures on spectra with sharp H and K lines are in accord with the belief expressed by Frost in *Astrophysical Journal*, **29**, 234, 1909. According to the measures of Burnham, *θ Virginis* has two companions: B, 9th magnitude, where $d = 7''.1$, $p = 344$; C, 10th magnitude, where $d = 64''$, $p = 295$.

The spectroscopic binary period is probably in the neighborhood of four months.

o 78 Virginis ($\alpha = 13^h\ 29^m$; $\delta = +4°\ 10'$; Mag. $= 4.9$)

Plate	Date		G. M. T.	Taken by	No. of Lines	Velocity	Quality
						km	
IB 665	1906	Jan. 26	22^h33^m	B	17	− 8.2	e.
717		Mar. 30	19 10	B	19	+ 1.2	e.
1042	1907	Apr. 26	18 43	F	14	−10.8	g.
1492	1908	Feb. 20	21 50	B	17	−13.0	e.

This star is also of type Ia2, and resembles θ *Virginis* in having many excellently defined lines.

24 o^2 *Canis Majoris* ($\alpha = 6^h\ 59^m$; $\delta = -23^\circ\ 41'$; Mag. = 3.1)

Plate	Date		G. M. T.	Taken by	No. of Lines	Velocity	Quality
						km	
B 495	1903	Feb. 5	$15^h 57^m$	A	5	+45.4	f.
A 419		Mar. 13	13 20	A	4	+48.3	g.
IB 524	1905	Mar. 3	15 36	F	5	+55.2	f.
897	1906	Oct. 31	22 06	B	8	+50.4	v. g.
911		Nov. 4	23 35	Fox	6	+56.4	g.
924		Dec. 14	18 27	Fox	3	+49.3	f. w.
1252	1907	Nov. 25	21 35	B	6	+49.2	g.
1338	1908	Jan. 17	18 39	B	8	+54.6	v. g.

The star has an *Orion* type spectrum with fair lines. Though the range of 11 km per second is small, the binary character seems certain. Plate B 495 gives the mean of measures by Adams and Mitchell, A 419 the mean of three measures by Adams, Mitchell, and Miss Harpham. Plates 524 to 924 were measured by Miss Harpham.

ζ *Canis Majoris* ($\alpha = 6^h\ 16^m$; $\delta = -30^\circ\ 1'$; Mag. = 3.1)

Plate	Date		G. M. T.	Taken by	No. of Lines	Velocity	Quality
						km	
IB 498	1905	Feb. 3	$16^h\ 1^m$	F	8	+22.9	g.
507		Feb. 6	15 41	F	5	+32.3	g.
642		Dec. 15	18 43	F	5	+40.2	f.
984	1907	Feb. 16	14 24	F	5	+24.4	g.

ζ *Canis Majoris* is an *Orion* type star. The above measures, indicating the spectroscopic binary character of the star, were made by Miss Harpham in May 1908. In the meantime, the observations of the star at the Santiago Station of the Lick Observatory by Messrs. Curtis and Paddock have been published (*Lick Observatory Bulletin*, No. 146; *Astrophysical Journal*, **29**, 229, 1909). The results for the first two plates above do not seem to confirm their surmise that the period is long.

COLUMBIA UNIVERSITY
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